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LOAN DOCUMENT

History of Research

in

Space Biology and Biodynamics

at the

Air Force Missile Development Center
Holloman Air Force Base, New Mexico

1946 - 1958

Historical Division
Office of Information Services
Air Force Missile Development Center
Air Research and Development Command
Holloman Air Force Base, New Mexico

Much of the important basic research in subgravity and zero-g has been performed by men of the Aeromedical Field Laboratory at the Air Force Missile Development Center. In this third chapter, Dr. Bushnell has traced the history of local contributions to this field of study. He has also placed this effort into the broader context of subgravity research accomplished elsewhere, especially in the United States, Argentina and the Union of Soviet Socialist Republics.

The next major subject of consideration is the history of research in escape physiology from 1953 through 1958. In the fourth chapter, Dr. Bushnell has documented those aspects of biodynamics research related to the punishing effects of windblast and the tremendous forces of abrupt deceleration encountered during emergency escape from high-mach aircraft. He has also mentioned the application of this experimentation to the effects of the magnitude and relatively long duration of g-loading experienced during sustained acceleration of multistage space vehicles. All the drama of human volunteer subjects taking part in rocket- and catapult-propelled sled experiments is a part of this colorful history of research at the Air Force Missile Development Center and elsewhere.

Scientists and technicians of the Aeromedical Field Laboratory have made important contributions in many other fields of biodynamics research. In addition to their achievements related to escape physiology, such as establishing the limits of human toleration to the windblast and deceleration forces experienced in emergency escape from high-performance aircraft, they have probed deeply into a variety of other biodynamics problems. Some of these concern aircraft and automotive crash forces, the stresses to be encountered in the atmospheric re-entry of manned space vehicles and satellites, and pure unapplied research in biodynamics designed to advance the sum of knowledge related to human reaction to various physical forces. These latter aspects of the history of such research at the Air Force Missile Development Center and at other important research establishments are the subject of Dr. Bushnell's fifth chapter.

All of these achievements in space biology and biodynamics--and the many other important accomplishments of the Aeromedical Field Laboratory staff--are the result of the application of knowledge, conviction and personal courage. They are also the result, however, of the administrative organization and direction of the laboratory's human resources, of the always-meager funds, and of the research projects themselves. For this reason, an understanding of the administrative successes and failures which have directed the Air Force Missile Development Center's conquests of the limitless vertical frontier are of value to any further planning related to man's invasion of outer space.

In the final chapter of this volume, Dr. Bushnell examines the administrative origin and development of the Aeromedical Field Laboratory. He has sought to identify the problems which have inhibited even greater accomplishment, and the methods of solution applied to those successfully resolved. More than this, he presents an objective account of the organization of the individual research projects, how they have been initiated, modified, expanded, combined, or cancelled.

On the whole, this volume would appear to have a special value of importance in addition to its detailed account of scientific endeavor in human factor research. Without much doubt, the Aeromedical Field Laboratory is nationally the best known of all the local organizations, despite its relatively modest quotas of funds and manpower. This relative notoriety is the result of several factors. Many of its leading figures, such as Colonel John Paul Stapp, Lieutenant Colonel David G. Simons and Dr. Harald J. von Beckh, are indeed colorful personalities. Another reason is that most of its activities can freely be written about or discussed without fear of security classification violations. Also, inherently present in so much of the laboratory's project workload is the element of human interest.

Yet the mere fact that the Aeromedical Field Laboratory is widely known and discussed does not mean that a balanced picture is always given. Basic progress in one area of research has often been overshadowed unduly by more sensational highlights in another. Nor has it always been fully realized to what extent present accomplishments are a logical outgrowth of programs that have been underway at Holloman Air Force Base in some cases since 1946.

For all of these reasons, the Historical Office has felt that a comprehensive history of biodynamics and space biology research at this installation is genuinely needed. The

FOREWORD

Since its inception a half-century ago, the United States Air Force has constantly operated higher and higher, faster and faster, until it has all but shattered the barriers of physical forces and alien physical environments which throughout all history have confined the activities of man to the immediate vicinity of the earth. With every advance in velocity and altitude resulting from new types of high-performance aircraft, rockets or satellites, the potential operational environment of the Air Force has expanded until today the actual area of operations extends to the very borders of interplanetary space and the immediate potential includes the vast central portion of the solar system. And with every advance of the environmental parameters, man encounters physical and biological hazards unique in his experience.

For many years, scientists of the Biodynamics and Space Biology Branches and more recently organized units of the Air Force Missile Development Center's Aeromedical Field Laboratory have sought to identify and understand the nature of these hazards, and to perfect protective devices and techniques for the benefit of man operating at high altitudes within the atmosphere and in the limitless space beyond. Because of the nature of its projects, the Laboratory occupies a unique position among the many other major units of the Center. It is one of the units working most directly toward man's ultimate conquest of space--and was actively working toward this objective even during the years that "space work" was in official Air Force and Congressional disfavor as "impractical."

In the study here presented, Dr. David Bushnell of the Center's Historical Office has carefully documented the history of this effort. In successive chapters, he has considered the many facets of these important contributions. First of all, he has examined the early beginnings of space biology research at what has since become the Air Force Missile Development Center--from 1946 until 1952. This is the period when the first such biological experiments of this program were attempted, when even rudimentary techniques for placing these experiments into the proper environment by means of balloons and rockets had to be devised, and when the program received its direction from a parent laboratory far distant from the scene, a laboratory in which an infant program of space biology could receive only a small amount of attention and possibly a smaller percentage of available research funds. The dawn of the second major period--when space biology research becomes part of the mission of the then newly created test, research and development center at Holloman Air Force Base--brings to a close this early portion of the history of such research at the Air Force Missile Development Center.

In his second chapter, Dr. Bushnell has recorded the scientific, technological and administrative victories and frustrations resulting in the major achievements of space biology research during the period 1953-1957. It is during this latter period that the fruit of earlier effort is harvested, and when, based upon these preliminary successes, bolder projects yield more significant and spectacular results.

Important technological advances, discussed in the initial portion of this chapter, contributed to outstanding accomplishments in two broad fields of space biology research--cosmic radiation and controlled artificial environments. Scientific and engineering progress in these latter fields is the main theme of this portion of the volume. The acquisition of this vital impersonal knowledge stemmed from dramatic events of high personal heroism as well as bold intellectual adventure, and frequent reference to these very human achievements has been a pleasant necessity.

The history of research in subgravity and zero-g, from 1948 through 1958, is the subject of Dr. Bushnell's third chapter. Weightlessness, the weird condition of subgravity which man had never before experienced and survived--except for the initial split-second of short-distance free fall--has become a major field of serious scientific research. Man now experiences this condition as his fast-climbing fighter flattens out to intercept a simulated enemy bomber, and he may soon experience it for long duration on multimonth interplanetary excursions. In recent years, man has gone to considerable expense and personal risk to fly Keplerian trajectories in high-performance aircraft in order to experience a force of less than normal gravity for fractions of a minute. Recently, a Soviet satellite exposed an animal subject to this condition for a period of several days. Gradually, a **corpus** of solid knowledge has formed as a result of these dramatic experiments, and man will go forth into space less inhibited by this psychophysical phenomenon than would otherwise have been the case.

present volume by Dr. Bushnell is designed to fill that need. It attempts an accurate but not too technical account of actual project research, and at the same time seeks to demonstrate how the Aeromedical Field Laboratory and its truly significant achievements have been related to work carried on at other institutions within the same general fields of study.

James Stephen Hanrahan
Chief, Historical Office
December 1958

ACKNOWLEDGMENTS

The six separate studies that make up this volume, describing different aspects of the work of the Air Force Missile Development Center's Aeromedical Field Laboratory, were neither produced on order for the Laboratory nor written by any members of its staff. They were produced as part of the Center's over-all historical program, and the Historical Branch bears full responsibility for all statements of fact or interpretation unless otherwise cited. Nevertheless, the volume would not have been possible without the wholehearted cooperation of the Aeromedical Field Laboratory staff, who made their entire files available to the Historical Branch and patiently answered innumerable questions concerning their work. Officers, enlisted personnel, and civilian employees all gave help, so that it would be almost impossible to thank each individual separately. In fact thanks are due not only to the present Laboratory staff but also to many who have since left--notably including Colonel John Paul Stapp, who headed the Aeromedical Field Laboratory until he departed in April 1958 for Wright Air Development Center to take charge of the Aero Medical Laboratory.

Help was also received from other members of the Aero Medical Laboratory at Wright Field; from the staffs of the Navy's Aviation Medical Acceleration Laboratory and the Air Force School of Aviation Medicine; and from the Directorate of Life Sciences at Headquarters, Air Research and Development Command. Scientists (and fellow military historians) at these other installations gave access to office records and submitted to more interviewing, both on joint projects in which they participated along with the Aeromedical Field Laboratory and on work of their own which must be taken into account in order to place the efforts of the Aeromedical Field Laboratory in true perspective. Two private organizations--Winzen Research, Incorporated of Minneapolis and the Convair (San Diego) Division of General Dynamics Corporation--have also supplied valuable data, as well as various illustrated materials, on the part that they played in bio-medical research and development efforts. The Winzen staff was of course primarily concerned with their participation in the Aeromedical Field Laboratory's Project Man-High. In the case of Convair, Dr. Robert Armstrong, of the Aviation, Space, and Radiation Medicine unit, made available information on the experimental Convair "B" ejection seat.

Then, too, many individuals assigned to the Air Force Missile Development Center in units other than the Aeromedical Field Laboratory gave important assistance to the preparation of this volume. An obvious example is Captain Joseph W. Kittinger, Man-High test pilot, who was actually assigned to the Center's Flight Test Division until his recent transfer to Wright Field. Naturally, much help was received from members of the Balloon Branch, which has given support to an impressive array of aeromedical research projects, and especially from its present Chief, Major Lawrence M. Bogard; from Major Milton M. Hopkins, Jr., who served the Branch in several different capacities; and from Mr. Bernard D. Gildenberg, who is head of the Balloon Control Section.

Others who supplied information include Major Hubert S. Williams, Commander of the 6580th Field Maintenance Squadron and a support pilot in Project Man-High; Mr. Ellis Bilbo, Chief, Plans and Programs Office, Directorate of Advanced Technology, and Mr. Charles S. Bagley, research scientist in the same Directorate; Master Sergeant Henry V. Carson, of the Center's Special Parachute Section; Dr. Knox T. Millsaps, Chief Scientist, and Lieutenant Colonel Harry L. Gephart, Executive, Office of the Chief Scientist, two former professors who have repeatedly delivered small lectures on unfamiliar details of scientific techniques and terminology. Lieutenant Colonel John W. McCurdy, who as Information Services Officer is practically an **ex officio** member of the Aeromedical Field Laboratory, supplied needed information and other assistance as well; so did Lieutenant Joseph G. Martin and Mr. George Meeter, of the same Office of Information Services. Technical Sergeant James W. Carter and his co-workers in the Center's Duplicating Services Section supplied no research data but deserve special credit for the quality of service they rendered when the different sections of this volume were originally published, during the course of 1958, in the form of separate monographs.

Last but certainly not least, other members of the Historical Branch have had an important part in preparing this volume. Dr. James S. Hanrahan, Center Historian, contributed many useful suggestions and has actually written certain passages of the finished

product. Mrs. Florence Clason, Editorial Clerk, has had the thankless task of deciphering and typing countless pages of illegible manuscript as well as helping to maintain the historical data files on which much of the manuscript was based.

David Bushnell,
Historian
December 1958

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THE BEGINNINGS OF RESEARCH IN SPACE BIOLOGY

1946 - 1952

The Man-High balloon flights of 1957--the second of which on 19-20 August carried Major David G. Simons aloft for more than thirty-two hours and to a space-equivalent height of over 100,000 feet--dramatically emphasize the varied mission performed by the Air Force Missile Development Center. All projects at this Center are related in some way to progress in the field of guided missiles and space vehicles, but by no means are all concerned with the actual development and testing of such objects. Project Man-High, for example, was designed and sponsored by the Center's Aeromedical Field Laboratory to explore the high-altitude environment in which men, missiles and high-performance aircraft will operate, rather than to test missiles themselves. Moreover, Man-High was not an isolated project but was the culmination of a history of investigations of physical and biophysical conditions of the extreme upper atmosphere and the borders of space which began at Holloman Air Force Base more than ten years before.

In the beginning, and in fact for a number of years, Holloman's function in aeromedical and related activities was primarily to render support services. The first instances of such support were in connection with the firing of V-2 rockets at nearby White Sands Proving Ground starting in 1946, even before the Air Force guided missile program was brought to Holloman. Not all V-2's fired at White Sands carried experiments of interest to aeromedical research, but many of them did for a variety of both governmental and academic organizations.[1]

Virtually all V-2 firings required some support from Holloman. This might consist of little more than providing a landing strip for aircraft carrying project people who would prepare the actual experiments or for the planeloads of high officials and other important visitors who would arrive to watch the final blast. Upon occasion, however, Holloman was called upon to lend laboratory facilities as well as vehicular support and housing for visitors. Such services were quite apart from the sharing of resources in routine day-to-day operations such as range management that has always existed between the Air Force Missile Development Center and White Sands Proving Ground without regard to the needs of specific projects.[2]

Space biology research began to expand as a field of practical interest shortly after the end of World War II. An early example of a biological experiment elevated to the extreme upper limits of the atmosphere was the exposure of fungus spores to cosmic radiation on the flight of 17 December 1946. This experiment was sponsored by the National Institutes of Health, and ended in failure since the lucite cylinders containing the spores were not recovered.[3] Experimentation techniques improved, however, and in the following year a container of fruit flies carried to an altitude of 106 miles was successfully parachuted back to earth where the flies were recovered alive and in apparent good health.[4] Still other examples of early experimentation could be cited.

The experiments with most direct bearing upon later activities of Holloman's Aeromedical Field Laboratory, however, were those sponsored by the Aero Medical Laboratory* at Wright-Patterson Air Force Base which sent live animals into the upper atmosphere above the New Mexican desert. The laboratory at Wright Field was the parent organization of the laboratory now part of the Air Force Missile Development Center, and many of the Wright Field aeromedical officers and civilian scientists involved in the V-2 research flights have also played a role in the origin and development of the Holloman unit. Similarly, the experiments themselves laid the groundwork for some of the space biology research accomplished later at Holloman Air Force Base.

The objective of the Aero Medical Laboratory's animal experiments at White Sands was clearly stated by the same David G. Simons, then a captain at the Wright Field establishment, who was the project engineer until after the second V-2 launching of the series:[5]

> Today there is no place on the earth's surface more than 40 hours travel from any other place

*The laboratory at Wright-Patterson Air Force Base employs the term aeromedical as two words in its title. Because of this the laboratory complex at Holloman is sometimes called the Aero Medical Field Laboratory, although responsible officials at the New Mexico installation use the gramatically preferred name Aeromedical Field Laboratory.

> so the question of the feasibility of travel beyond the reaches of the atmosphere inevitably arises. But what are the problems of space flight in a rocket? By theorizing, the various possible dangers and limiting factors can be appraised and appropriate means of protection against each surmised. However, only by actually performing the experiment can one prove or disprove the validity of the hypothesis, learn better ways of protecting against known hazards and realize for the first time, the existence of unsuspected dangers. Only the recovery of a live animal showing no demonstrable ill effects will permit the claim that no major difficulty has been overlooked.

Captain Simons, who had been a space-flight enthusiast since childhood,[6] implicitly revealed in this statement his ambition to rocket through space some day himself. Unfortunately, the live animal recovery he was hoping for was not effected on any of the five biological flights carried out at White Sands. These experiments did contribute importantly toward developing the techniques which produced live recoveries later, however, and valuable physiological data were recorded.

Never did the Aero Medical Laboratory have the luxury of a V-2 rocket all to itself. The Air Force Cambridge Research Center, however, offered some space in the "Blossom" series of V-2's which had been assigned to it, and the Laboratory was delighted to accept. Overall responsibility for aeromedical participation was assigned to Dr. James P. Henry, head of the Acceleration Unit of the Biophysics Branch, Aero Medical Laboratory, and a strong supporter of research in all biophysical problems likely to be faced at extremely high altitude. Working closely with Captain Simons and others at Wright Field, Dr. Henry set to work devising methods for conveying a small monkey to the upper limits of the earth's atmosphere in a V-2. Some sort of pressurized capsule to go inside the nose cone of the rocket was obviously needed, but the available space was extremely limited and there were few precedents to go by. The outside environment against which the capsule was to afford protection was one that no mammal had yet penetrated.[7]

Nevertheless, the capsule was made and the scene of operations shifted to New Mexico for the final preparations. Early in the morning of 18 June 1948, a nine-pound anaesthetized rhesus monkey was sealed inside the capsule, which in turn was placed in the nose of a V-2 rocket. Because the monkey's name was Albert the entire operation became known as the Albert (I) Project.

Unfortunately, the project was plagued with a whole series of operational failures. The apparatus for transmitting respiratory movements failed even before the time of launch. This probably made no real difference, though, because there are indications that Albert died as a result of breathing difficulties in the cramped capsule before his rocket left the ground. Even the parachute recovery system devised to lower the nose cone with its animal capsule back to earth failed to function properly, and Albert would have been killed upon impact even if he had not died previously. The recorder placed within the capsule was successfully recovered and it showed no evidence of physiological activity at any time during the flight--which could mean either that the animal was dead from the outset or that there had been a complete failure not only of the mechanism for recording respiration but also of the electrocardiographic apparatus that was also attached to the subject.

The net result of the first Albert project, then, was experience for the scientists who had taken part in it and the incentive to do better next time. This they succeeded in doing. For the second experiment, which took place a year later on 14 June 1949, the capsule was redesigned to let the subject (Albert II) assume a less cramped position. The instrumentation was also improved, and so was the parachute recovery system. The latter still was not improved enough, however, and Albert II died at impact, but respiratory and cardiological data were successfully recorded up to that moment.

Thus it was established that a monkey had lived during an entire flight which reached an altitude approximately eighty-three miles above the surface of the earth. The evolution of engineering techniques was making possible greater success in the scientific exploration of physiological factors related to space flight. Although not necessarily a direct cause of this greater success, the fact is that Holloman's participation was also greater in the second Albert experiment than in the first. For the first experiment, Holloman provided a landing field for visiting aircraft and a

certain amount of vehicular support. For the second experiment, Holloman provided all this and laboratory space besides. The final preparation of the nose cone took place at Holloman rather than at White Sands Proving Ground.[8]

The third V-2 animal experiment was marred by unsatisfactory rocket performance and journeyed vertically only a few miles, but the fourth again reached the desired altitude. It followed a pattern identical with that of the second experiment; the successful recording of data from a living primate throughout the flight with parachute failure causing death at impact. In neither case did the heart and respiratory data recorded give any sign of "gross disturbance" as a result of rocket flight nearly to the limits of the earth's atmosphere.

To be sure, it had not been expected that during the few minutes' exposure such as during the V-2 experiments there would be evidence of damage from cosmic radiation. Even if harmful effects from cosmic rays did occur, they would presumably have been detected by careful examination afterward, and this was impossible because of failure to recover the animals alive.[9]

Neither were the forces of acceleration and deceleration during the flights of an order expected to cause injury. On the second flight, for instance, the peak g-forces were 5.5, only five and a half times the normal effect of gravity, during rocket motor acceleration, and twelve or thirteen g's at the opening shock of the parachute recovery system (which later failed). It has since been established that these figures are well within the tolerance limits of a properly secured subject.

There remained the possibility of harm to the subject from the period of subgravity and actual zero-gravity (weightlessness) experienced between rocket burnout and return to a point where atmospheric resistance again became appreciable. Even though exposure during a V-2 test was brief, any ill effects of a subgravity state would be expected to appear at the time of flight. When none in fact appeared it was logical to conclude, at least tentatively, that a brief subgravity trajectory offered no major physiological hazards.

In order to explore subgravity effects more fully, the fifth and final V-2 experiment of the Aero Medical Laboratory introduced a new procedure. This time, in the summer of 1950, a mouse was used as the subject instead of a monkey and no attempt was made to record heart action or breathing. Unlike the monkeys, the mouse was not even anesthetized because the purpose of the experiment was to record the conscious reactions of an animal to changing gravity conditions. For this purpose, the mouse capsule was equipped with a camera system to photograph the mouse at fixed intervals.

As usual, the recovery system failed--the mouse did not survive the impact. But the photographs came through successfully and showed that the mouse retained "normal muscular coordination" throughout the period of subgravity, even though "he no longer had a preference for any particular direction, and was as much at ease when inverted as when upright relative to the control starting position."[10]

Even before this last V-2 blasted off toward space, scientists of the Aero Medical Laboratory were making plans to continue their experiments using the newly-developed Aerobee high-altitude rocket, which was specifically designed for research purposes. Although the test program was still to be directed from laboratory headquarters at Wright Field, launch operations and much other activity now shifted wholly to Holloman, where the Air Force missile program had started to prepare an Aerobee test facility as early as 1948.

The first Aerobee did not streak skyward from Holloman until December 1949, however, and the first aeromedical Aerobee did not get off until 18 April 1951. When it finally went, it carried an experiment basically similar to those of the first aeromedical V-2's--a monkey fully instrumented to record breathing and heart rates. And the result was familiar also; physiological data successfully recorded, no sign of "gross disturbance" in the subject--and the parachute failed again.[11]

Finally, when the second aeromedical Aerobee was fired 20 September 1951, the long-awaited breakthrough in parachute recovery was successfully accomplished. This vehicle carried an arkful of animals to an altitude of 236,000 feet and brought them all back alive. Included in the menagerie were a monkey instrumented to record heart beat, respiration and blood pressure; nine mice who went along simply to be exposed to cosmic radiation; and two other mice in a rotating drum for the photographic observation of their reactions to subgravity.

Two hours after impact the monkey died, but data recorded during flight as

well as the later autopsy suggested that death was not the result of any ill effects of the flight but rather of landing shock or heat prostration, or probably both. There had been a slight delay in retrieving and opening the capsule after it was successfully parachuted down and the monkey's small compartment became much too hot in the midday sun of southern New Mexico. Two of the eleven mice also died following recovery but none showed any apparent ill effects from cosmic radiation.

In the subgravity experiment, one of the two mice in the rotating drum had undergone a prior operation removing the vestibular apparatus that gives mammals a sense of equilibrium. He was already accustomed to orient himself by vision and touch exclusively and did not seem affected by loss of gravity during the flight. He had no trouble holding on to a small projection in the side of the drum. The other mouse, which was normal, clawed at the air and appeared definitely disturbed during the subgravity phase of the trajectory.[12]

The third and last aeromedical Aerobee, fired 21 May 1952, was still more successful. Not only were all passengers--two mice and two monkeys--brought back alive from the upper atmosphere, but they were also rescued in time from the New Mexico sun. This time both mice were normal, and again they were placed in a rotating drum. One had a paddle to cling to and one did not, and the photographs taken in flight showed that "if given the opportunity to use his tactile sense and cling to something, an animal will remain oriented and quiet" during exposure to subgravity.[13] The mouse with nothing to cling to showed some signs of temporary disorientation during the interval of complete weightlessness, although that interval was too short to permit any firm conclusions.

As for the two monkeys, they were arranged in contrasting positions, one seated upright and the other supine, and the recorded physiological data indicated that neither suffered any harm. Their trip was distinguished merely by the fact that they were the first primates to reach the extreme upper atmosphere--thirty-six miles to be exact--and survive. Both were presented to the National Zoological Park of the Smithsonian Institute in Washington, D. C., where one subsequently died from causes unrelated to rocket flight and the other is still alive and healthy.[14]

It is interesting to note that the V-2 and Aerobee aeromedical flights aroused strong complaints from certain animal lovers in the United States and abroad, but the flights also inspired a surprising number of human volunteers to write and offer themselves as passengers in the next rocket. Such offers have come to Holloman from as far away as the Philippines. Often, although not invariably, they have been made by persons hoping to pay some debt to society by gathering scientific information at considerable risk and inconvenience to themselves. One offer, in fact, was submitted in November 1956 by a resident in the Washington State Penitentiary.[15]

On the whole, the development of rocketry techniques between 1946 and mid-1952, including the perfection of vehicle recovery systems, was important in the evolution of space biology as a field of practical research. These engineering successes had permitted significant scientific accomplishment during these early years in cosmic radiation, subgravity phenomena and other areas of interest. V-2's and Aerobees, however, were only two methods of lofting biological and other experiments to the borders of interplanetary space, as other developments at Holloman during these same years will indicate.

The first completely successful high-altitude animal flight at Holloman Air Force Base was not one of the Aerobee rocket firings. The honor goes instead to a balloon that carried eight white mice to 97,000 feet on 28 September 1950. This achievement formed part of still another research venture of the Wright Field Aero Medical Laboratory and, like the Aerobee flights, was conducted under the general auspices of Project MX-1450R, Physiology of Rocket Flight.[16]

The Aerobee flights were primarily concerned with exploring subgravity conditions and only incidentally carried cosmic radiation experiments. The September balloon flight and other balloon experiments in the same series were primarily intended to determine the effects of cosmic rays upon biological specimens. The use of balloons did not conflict with the term "Rocket Flight" as found in the project title because one of the environmental factors on which data would be needed whenever long-range manned rockets became available was obviously the effect of cosmic radiation upon passengers and crew. For the moment, no rocket was capable of staying at high altitude long enough to expose living subjects to such rays for more than a few minutes, and for radiation studies this was not enough. Balloons, on the other hand, could maintain

high altitudes for prolonged periods and obtain required research data at very low cost--thanks in large part to improvements in balloon manufacture and balloon techniques that occurred since World War II.

The basic innovation was the introduction of balloons made of polyethylene, a plastic material between one- and two-thousands of an inch thick and very strong. Plastic stratosphere balloons were pioneered chiefly by Mr. Otto C. Winzen of Minneapolis, who helped organize the aeronautical laboratories of General Mills, and who formed Winzen Research, Incorporated, his own concern, in 1948. Unlike rubber-type balloons, these did not expand as they rose. Or, to be exact, the plastic material was nonextensible and the cell was filled with gas to only a fraction of its capacity at launch, the gas expanding as the balloon climbed through lesser pressures until it entirely filled the capacity of the balloon at ceiling. Such balloons were much more stable, permitting long-duration, constant-level flights and better control. They could carry far greater payloads, which was an obvious advantage for research purposes. And they even brought an extra touch of romance to space biology, since the plastic surfaces, glistening in the sun, led to frequent confusion with flying saucers.[17]

Furthermore, much of the post-war development in balloon research had actually taken place at Holloman Air Force Base, which was therefore well qualified to handle the series of aeromedical flights. Holloman's first polyethylene research balloon was launched 3 July 1947 by a New York University research team. This was twenty days before the historic first of Holloman's missiles climbed high over the vast test range.[18]

From this first Holloman balloon launch until August 1950, numerous research flights were undertaken at Holloman obtaining physical data on the upper atmosphere in support of a wide variety of projects. Some of these balloon-transported experiments, notably those exposing cosmic ray track plates to high-altitude radiation, contributed to the research groundwork for the later biological experiments, but apparently none were designed expressly for biophysical research. Also, part of this early balloon activity used old-style extensible balloons made of rubber or similar material. Yet every flight, regardless of research objectives or balloon material, contributed in some way to build up a remarkable launch and recovery capability at Holloman. These operations in the beginning had depended to a large extent upon visiting technicians and borrowed equipment. By 1950, however, the base had its own organized Balloon Unit and offered efficient launch and recovery services for both local and off-base projects.[19]

The first of the balloon flights launched for the Aero Medical Laboratory took place 29 August 1950, a month before the record-making mouse flight. It was strictly for practice, carried no animal subjects and, like all subsequent aeromedical flights, used a polyethylene plastic vehicle. It was launched at 0530 from the picnic area of White Sands National Monument, soared to an altitude of between five hundred and a thousand feet and then descended ingloriously about half a mile from the launch site. A second practice flight later that day reached 67,000 feet and was judged successful. It was followed by the first attempted animal flight, on 8 September, which was unsuccessful; the balloon reached only 47,000 feet and all "14 or 16" mouse subjects were dead when recovered as a result of capsule leakage and depressurization. The fourth flight, 16 September, carried equipment only, but the fifth flight was the one on 28 September that took eight mice to 97,000 feet. One of the mice died en route back to the base after landing, but autopsy indicated that the death was due to pulmonary inflammation rather than to cosmic rays or events of the flight.[20]

Between 28 September 1950 and the end of 1952 the Balloon Unit launched twenty-one more aeromedical balloon flights. These were coming to be regarded as a regular Holloman activity even though the conduct of the program remained under the ultimate direction of the Aero Medical Laboratory, and of Dr. Henry, in particular, who was the same individual that had directed the first V-2 animal flights.

Some balloon flights carried nonbiological payloads such as cosmic ray track plates and experimental equipment, and the animal tests now progressed from mice to hamsters, cats and dogs--even fruit flies being represented. The usual flight plans called for altitudes in the neighborhood of 90,000 to 100,000 feet with durations gradually increasing until they reached twenty-eight hours. To be sure, full specifications were not always met since roughly half the flights experienced either balloon failure (complete or partial) or some other type of equipment trouble. In still other cases, balloon and equipment functioned properly but recovery of the flight capsule was delayed too long for the test subjects

to remain alive. In fact, out of eleven flights in all (including those of September 1950) that involved insect or animal subjects, only two could be counted as wholly successful, although others enjoyed partial triumphs. Such problems were inevitable in a young art like research ballooning, and above all in the aeromedical branch of that art which has always presented special complications.[21]

One complication shared with all other projects that required long-duration flights was the difficulty of maintaining ceiling altitude with a plastic balloon at night, due to the cooling and contraction of the gas. This could be overcome by dropping ballast, but the operation was not easy. A complication present only in aeromedical flights was the need to provide a controlled environment for biological specimens. This required careful balancing of a great many factors. For instance, by adding more animals to a capsule it was possible to reduce or even eliminate the need for artificial heating at night, but only at the cost of increasing the requirements for oxygen supply and daytime cooling. Atmospheric controls also involved apparatus whose bulk and weight had to be taken into account when planning a flight. Last but certainly not least, animal flights required unusual precision in recovery in order to bring the specimens back alive. The fate of the monkey on the second aeromedical Aerobee showed what could sometimes happen with even a slight delay in reaching the capsule. Environment controls normally were not adequate both to protect the specimens in flight and to protect them for any considerable length of time after landing.[22]

People of the aeromedical projects and of the Holloman Balloon Unit were working hard to bring these and related problems under control, even though their work did not start to bear fruit on a very noticeable scale until the period from 1953 to the present--which is discussed in a later installment of the history of aeromedical research at the Air Force Missile Development Center. During this early period, the Balloon Unit brought to space biology flights the benefit of its continuing work with other projects. An interesting example is the so-called "covered wagon" launch method, which was devised at Holloman specifically for Project Moby Dick, an Air Force study of high-altitude wind fields. The covered wagon was a flat-bed trailer with high headboard and nylon top, in which a balloon could be protected from winds during inflation. Most research balloons today have outgrown the dimensions of a covered wagon launcher, but the method was used successfully on several of the 1952 aeromedical flights with balloons 72.8 and 85 feet in diameter.[23]

Research ballooning at Holloman and elsewhere benefited further from the experimental work of organizations such as Winzen Research, Incorporated and General Mills--the two leading manufacturers of plastic balloons--and the University of Minnesota, which was engaged in a continuing effort to improve balloon performance under a contract from all three armed services.[24] Both New York University and the University of Minnesota designed animal capsules for use at Holloman, and a University of Minnesota faculty member, Dr. Berry Campbell, took part in the post-flight examination of test specimens under a separate Air Force contract.[25]

However, even when no operational difficulties arose, the aeromedical flights to and including those of 1952 did not produce much useful biological information. The animal subjects, if successfully recovered, showed no signs of radiation damage. But this fact in itself proved little since evidence was accumulating to the effect that no significant amount of cosmic radiation penetrates to the 90,000-100,000-foot level south of 55° north geomagnetic latitude,[26] and Holloman Air Force Base is located at 41° north. In technical terminology, flights at Holloman gave exposure to light primary particles and "stars" but to practically no multibillion-electron-volt heavy nuclear "thindowns." Therefore, the early flights were important mainly for the additional experience they provided in the way of balloon techniques, and for developing "control" data that would help later in evaluating data obtained at higher latitudes.

There was at least one other project involving aeromedical research that made use of Holloman facilities during the period under consideration, although not necessarily related directly to space biology. A joint team representing both the Aero Medical Laboratory and the Equipment Laboratory at Wright Field came to Holloman in 1950 to test improvements in high-altitude escape procedure. They were especially interested in a device preset to open a parachute automatically after a flier falls to the level where there is sufficient oxygen to breathe. While they were in New Mexico, one member of the team, Captain (now Major) Vincent Mazza, set a new record by dropping from an airplane at an altitude of 42,176 feet. Another volunteer in these tests, Master Sergeant (lat-

er Captain) Jay D. Smith was assigned to Holloman, rather than Wright Field. Although the local base gave extensive support to the project, the principal project people were visitors to Holloman on temporary duty.[27]

The aeromedical Aeorbee firings and the cosmic radiation balloon program both involved considerable temporary-duty travel between Holloman and the directing laboratory at Wright Field in Ohio. This system was proving impractical in certain respects, for the preparations for rocket and balloon flights were elaborate and time-consuming and required more or less permanent laboratory facilities. Although the balloon program obtained launch and recovery services from the facilities and people of the Holloman Balloon Unit, the space biology project officers also needed decent accommodations for hamsters and fruit flies which the standard base support organization was poorly equipped to offer.

For all these reasons, it became necessary to create a special unit at Holloman--the Aeromedical Field Laboratory--under the original direction of Lieutenant James D. Telfer. This step was taken officially about the middle of 1951, and the first permanent building ever constructed expressly for use by the new unit appears to have been ready in October of that year.[28]

Lieutenant Telfer and other officials of the Aeromedical Field Laboratory were still technically assigned to the parent organization at Wright Field, although they were present at Holloman on an indefinite basis. In practice, Lieutenant Telfer, who was himself a geneticist, was delegated a large amount of independent responsibility in directing the balloon flights (although not the Aerobee firings). Another development of considerable significance later was the formal creation within Holloman's 6540th (later 6580th) Missile Test Group of an Aero-Medical Sub-Unit which was endowed with the specific function of providing a "small group of Holloman Air Force Base personnel to support [the] Aeromedical Field Laboratory."[29]

Gradually, the facilities and people for a significant program of space biology and other aspects of research related to human factors in rocket flight were accumulating at the installation which was later to evolve into the present Air Force Missile Development Center. The gathering of human and material resources, however, was only one of the important contributions of this early period. Equally important were the experience gained in rocket and balloon launching, instrumentation and recovery techniques, and the collection of a growing body of scientific data related to cosmic radiation and subgravity problems which would prove very useful in later programs. In various manners, the years 1946 through 1952 at Holloman marked the practical beginning of Air Force research in space biology.

NOTES

1. Homer E. Newell, Jr., **High Altitude Rocket Research** (New York, 1953), pp. 30-33, offers a table of V-2 firings with a brief notation of the experiments carried in each case. To be sure, this table must not be taken literally when it attributes particular tests to Air Research and Development Command long before the command was created.

2. Concrete examples of Holloman-White Sands cooperation in general support and administrative functions are discussed in other publications of the Air Force Missile Development Center's Historical Branch. See especially **Integration of the Holloman-White Sands Ranges, 1947-1952** (2nd edition, 1957), and **History of Flight Support, Holloman Air Development Center, 1946-1957** (July 1957).

3. L. W. Fraser and E. H. Siegler, **High Altitude Research Using the V-2 Rocket, March 1946-April 1947** (Johns Hopkins University, Bumblebee Series Report No. 8, July 1948), p. 90.

4. Kenneth W. Gatland, **Development of the Guided Missile** (London and New York, 1952), p. 188.

5. Capt. David G. Simons, **Use of V-2 Rocket to Convey Primate to Upper Atmosphere** (Wright-Patterson Air Force Base, AF Technical Report 5821, May 1949), p. 1.

6. Cf. **Scope Weekly,** 3 October 1956, p. 7.

7. A popular account of the Aero Medical Laboratory's V-2 experiments is offered by Lloyd Mallan, **Men, Rockets, and Space Rats** (New York, 1955), pp. 84-93. This should be read in conjunction with the technical paper by Captain Simons, cited in the above footnote, and the article by Dr. James P. Henry, **et al.,** "Animal Studies of the Subgravity State during Rocket Flight," **Journal of Aviation Medicine,** Vol. 23, pp. 421-432 (October, 1952).

8. Interview, Maj. David G. Simons, Chief, Space Biology Branch, Aeromedical Field Laboratory, by Dr. David Bushnell, AFMDC Historian, 6 September 1957.

9. Simons, **Use of V-2 Rocket,** p. 22; interview, Maj. Simons by Dr. Bushnell, 13 December 1957.

10. Henry, **et al.,** "Animal Studies of the Subgravity State," **loc. cit.,** p. 428.

11. **Ibid.,** p. 425.

12. **Ibid.,** pp. 423, 424, 429-431; **Final Test Report, USAF Aerobee No. 19,** 19 February 1952; "Historical Report, Holloman Air Force Base. . . 1 September 1951-31 October 1951," pp. 104-107; Maj. David G. Simons, "Review of Biological Effects of Subgravity and Weightlessness," **Jet Propulsion,** May 1955, p. 211.

13. Henry, **et al.,** "Animal Studies of the Subgravity State," **loc. cit.,** p. 429.

14. **Ibid.,** pp. 425, 429; Florence Clason, typed summary of Aerobee flights in Historical Branch files; **Alamogordo Daily News,** 1 December 1957; Maj. Simons, "Biological Effects of Subgravity," **Jet Propulsion,** May 1955, p. 211.

15. Lt. Col. (later Colonel) John P. Stapp, Chief, Aeromedical Field Laboratory, HADC, noted in September 1955 that an "indignant letter from a mouse-loving lady in England" arrived three years after the first publicity on the Aerobee flights (ltr., Lt. Col. Stapp to Otto C. Winzen, 21 September 1955). A typical human volunteer letter come from Ernesto S. Veloso, Cebu City, Philippine Republic, 21 January 1956, addressed to "U. S. Air Force Laboratory, Alamogordo, N.M." The letter was answered by Maj. Simons on 17 February 1956, respectfully declining this "very patriotic" offer on technical grounds. The offer from Washington State Penitentiary was addressed by an inmate on 27 November 1956 to Dr. Hubertus Strughold of the School of Aviation Medicine; Dr. Strughold referred it to Holloman, where it was duly answered by Maj. Simons on 10 January 1957.

16. "Historical Report, Holloman Air Force Base . . . 1 September 1951-31 October 1951," p. 106; Maj. David G. Simons, **Stratosphere Balloon Techniques for Exposing Living Specimens to Primary Cosmic Ray Particles** (HADC Technical Report 54-16, November 1954), p. 11.

17. Simons, **Stratosphere Balloon Techniques,** p. 6 and **passim;** Winzen Research, Inc., "Rebirth of the Balloon" (Minneapolis, n.d.); interviews, Mr. Bernard D. Gildenberg, Chief, Technical Support Section, AFMDC Balloon Branch, by Dr. Bushnell, 18 and 30 September 1957.

18. The first research balloon flight of any sort at Holloman had been slightly earlier, 5 June 1947; this involved a cluster of rubber-type balloons (interview, Mr. Gildenberg by Dr. Bushnell, 18 September 1957).

19. The principal source of data on early balloon operations is the monthly section on "Electronic and Atmospheric Projects" in **Progress Summary Report on U.S.A.F. Guided Missile Test Activities,** which was published at Holloman on a monthly basis from 1 November 1947 to 1 July 1950 (and then continued for a while as a quarterly). Other data have been obtained from the interviews with Mr. Gildenberg already cited.

20. Simons, **Stratosphere Balloon Techniques,** pp. 11-12.

21. **Ibid.,** pp. 12-19.

22. **Ibid.,** pp. 1, 4-10, 51-59.

23. **Ibid.,** pp. 7, 18-19; "Historical Report, Holloman Air Force Base. . . 1 September-31 October 1951," pp. 88-90; "Historical Report, Holloman Air Force Base. . . 1 November-31 December 1951," pp. 82-86; interview, Mr. Gildenberg by Dr. Bushnell, 18 September 1957. The diameters cited refer, of course, to a balloon filled by expansion of the gas to its full capacity, as at ceiling altitude.

24. See Department of Physics, University of Minnesota, **Progress Report on Research and Development in the Field of High Altitude Plastic Balloons,** published in various installments.

25. Simons, **Stratosphere Balloon Techniques,** pp. 1, 5-6, 10, 56-57.

26. **Ibid.,** pp. 1-2.

27. **Rocketeer** (HAFB), 29 September 1950; Capt. Vincent Mazza, "High Altitude Bailouts," **Journal of Aviation Medicine,** Vol. 22, pp. 403-407 (October 1951); Memorandum Report, **High Altitude Bailouts,** WADC, 1950.

28. **Holloman AFB Reference Book,** June 1952, p. 7; building data card on Building 1201, in Real Estate Section, Installations Division; interview, Maj. Simons by Dr. Bushnell, 13 December 1957; **Stratosphere Balloon Techniques,** p. 4. The Laboratory also had a second building, which was a wartime "temporary" structure converted to use as housing for animals (building data card on Building 1203).

29. Comptroller, HAFB, Organization and Functions, April 1952, p. 82; interview, Maj. Simons by Dr. Bushnell, 17 December 1957.

II

Major Achievements in

SPACE BIOLOGY

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

1953-1957

LT. COLONEL DAVID G. SIMONS

MAJOR ACHIEVEMENTS IN SPACE BIOLOGY

1953 - 1957

Many projects at the Air Force Missile Development Center contribute directly to man's efforts to explore the vertical frontier and to probe into space far beyond the earth's atmosphere. It is the Space Biology Branch of the Aeromedical Field Laboratory, however, that is most concerned with man himself crossing this threshold, and which is preparing the way for manned satellites and piloted space vehicles. Headed by Doctor (Major) David G. Simons since the formal creation of the unit at Holloman Air Force Base in 1953, scientists and technicians of this organization have been pursuing a series of research tasks which, since 1954, have been grouped together as Project 7851--Human Factors of Space Flight.

Research in space biology during three years has yielded significant results concerning human reaction to subgravity or zero-g conditions, problems of human reentry into the earth's atmosphere, and other matters of importance. Research in the Biodynamics Branch of the Aeromedical Field Laboratory concerning the effects of abrupt and sustained acceleration and deceleration is also important in understanding the physiology of human rocket flight. All these topics will be treated in forthcoming historical studies. In the pages which follow here, however, attention will center primarily upon major achievements in three specific areas of endeavor.

One of the principal themes of this study is research concerning the effects of cosmic radiation on human and other forms of life. A second major topic is the development of a true space capsule for long-duration, high-altitude, space-equivalent flights--culminating in the Man-High balloon ascent of 19-20 August 1957 by Major Simons. Before considering these subjects, however, it will be useful to discuss briefly certain technological developments related to placing these experiments into proper environment and recovering them in time for further observations. Without these technical advances, outstanding accomplishments in the other areas of research would have been much more difficult if not impossible.

1. Important Technological Developments

Many of the techniques developed during the pioneering period 1946-1952 in the use of both rockets and balloons for space biology research[1] have continued to be useful in the later period of more intensive activity. Certain engineering techniques and methods of operation developed since then, however, have helped to make possible research accomplishments of far greater significance. Balloon operations from 1950 through 1952, for instance, provided a wealth of experience in balloon and capsule techniques, but only since 1953 have they amassed a significant quantity of data on such problems as the biological effects of cosmic rays.

The greater effectiveness of balloon flights from 1953 to the present has been partly the result of an increase in human and material resources devoted to the program. It also reflects the transfer of major launch operations to localities in the northern United States where, as now became apparent,[2] the magnetic field of the earth converging on the poles permitted a much more significant exposure to primary cosmic radiation than at comparable balloon altitudes at the latitude of Holloman Air Force Base, New Mexico. Since the spring of 1953, in fact, space biology flights conducted at Holloman have been primarily to test balloon and capsule techniques or to expose biological control specimens to the relatively weaker radiation of lower geomagnetic latitudes. Finally, since 1953 there has been a sharp technical improvement in flight performance due in part to previous efforts only now beginning to bear fruit, and in part to continuing research and development by aeromedical scientists, balloon manufacturers, and others, both at Holloman and elsewhere.

One noteworthy development, first employed on space biology flights in 1953, was the perfection of radio command cut-down as a method of terminating balloon flights. Two different command cut-down devices were used in that year, one developed by the Aero Medical Laboratory at Wright Field and the other provided by the aeronautical laboratories of General Mills. This new method did not replace but came to supplement the earlier preset timer, which had been inadequate by itself because it might automatically let down a balloon capsule during a thunderstorm that would interfere with both radio and visual tracking, or perhaps drop an experimental cargo into the heart of an inaccessible area. At least now the flight could

be shortened if these difficulties were anticipated.[3]

Tracking and recovery techniques also improved steadily. Panel trucks equipped as radio monitoring and tracking stations supplemented the work of tracking aircraft. Improved balloon-borne antenna systems permitted an equipment package to send reliable signals even after it landed, thus helping search parties to find it. Any improvements in tracking and recovery were of course particularly important for space biology flights, which have always required prompter recovery than most. A lost balloon capsule might be returned months later, in response to the twenty-five-dollar reward notice posted on it, but by then all biological specimens would have perished.[4]

Since 1953, environment control for animal capsules has likewise undergone considerable improvement. One of the most ingenious developments was the use of boiling water as a coolant, a system pretested in the Standards Laboratory at Holloman and successfully flight-tested on balloon missions in the fall of 1953. The device is based on the principle that, because of decreased atmospheric pressure, water boils at lower temperatures when placed at higher elevations. At an altitude of about 112,000 feet, for example, water boils at thirty-two degrees Fahrenheit--the temperature where at sea level it would become solid ice. Therefore, water could be made to boil at high altitude simply by placing it in a container vented to the lower outside atmospheric pressure. When air within the sealed capsule was circulated around the container, vapor from the boiling water carried off heat from the capsule.[5]

Other improvements of equal or greater importance were steps taken to reduce the over-all weight of the capsules. During 1954 and 1955, the weight of the standard animal capsule was reduced from one hundred sixty-five pounds to about seventy. The direct result of this accomplishment is that identical balloon equipment can now attain significantly higher altitudes with the same biological specimens.[6]

Flight performance also benefited greatly from continued improvements in balloon launch techniques. At Holloman, the "covered wagon" technique, whereby a small or medium-size balloon could be protected during launch by inflating it on a vehicle with high headboard and nylon top, had been perfected and used during the pioneering years. Next came the shroud-inflation technique, which held the balloon beneath a large fabric cap during inflation. This system was later improved upon by using the crane-launch method, in which the delicate cargo is carefully suspended from the crane's boom while the balloon cell, at the opposite end of the load line, is undergoing inflation. And, by the close of 1957, these techniques were giving way to still other newly-devised methods.[7]

To be sure, these and other innovations in balloon techniques were not perfected solely for space biology flights. The Holloman Balloon Branch launched 683 plastic-type balloons in fiscal years 1951 through 1957, and only a small fraction of these were for cosmic radiation studies or other tasks of the Aeromedical Field Laboratory. The shroud-inflation technique, for instance, resulted from an effort of the Holloman unit to meet requirements for the manned balloon phase of Wright Air Development Center's Project 7218, Biophysics of Escape. Space biology studies, however, benefited from all major technological improvements, including those developed away from the Air Force Missile Development Center by private balloon technicians; and, in turn, the experience accumulated on flights for the Aeromedical Field Laboratory was of benefit to other balloon operations.[8]

Meanwhile, the balloons themselves were growing both bigger and better. One landmark was the introduction of the two-million-cubic-foot plastic balloons. The first of these to be used on a cosmic radiation flight was manufactured by Winzen Research, Incorporated, and launched 18 July 1955 at Fleming Field, South Saint Paul, Minnesota. It reached an altitude of over 120,000 feet. It was followed by a similar balloon launched the very next day which reached 126,000 feet, a record not only for the Aeromedical Field Laboratory program but also (to that date) for polyethylene balloons in general.[9]

Neither of these balloons was intended to set a flight-duration record, but time aloft on individual flights was also increasing steadily. This fact, plus the growing reliability of flight performance and recovery, permitted much longer exposure of individual specimens by reflying them on two or more consecutive flights. Because of greater uncertainties in recovery, capsule performance, and the like, this procedure of multiple flights was virtually impossible prior to 1953, but since that time it has become commonplace. In 1954, for example, test specimens were reflown on two separate flights for a total of seventy-four hours and thirty-five minutes at an altitude between 82,000 and 97,000 feet, mostly above 90,000.[10]

2. Achievements in Cosmic Radiation Studies

Studies on the biological effect of cosmic radiation--designed to explore one of the possible hazards of human flight in space--originally came to Holloman as one aspect of the early Project RDO 695-72 (MX-1450R), entitled Physiology of Rocket Flight. During 1953 and most of 1954, the work continued under a new project title, Biophysics of Cosmic Radiation, and since then has continued as Task 78500, Radiation Hazards of Primary Cosmic Particles, within the framework of Project 7851.[11]

Many individuals have contributed directly to the accomplishments of this scientific study. One is Lieutenant Charles H. Steinmetz, who began work in October 1953 and became the first task scientist after the formal establishment of Task 78500. Two years later, on 1 October 1955, Lieutenant Harold H. Kuehn replaced Steinmetz and continued the work as task scientist until he left the Air Force early in 1958. Captain Druey P. Parks, who has shouldered a wide variety of assignments for the Aeromedical Field Laboratory, has also made important contributions to cosmic radiation studies, notably in the area of technical support. And a number of enlisted men assigned to the Space Biology Branch of the laboratory have helped to devise important new techniques while engaged in the day-to-day conduct of the program. Finally, Major David G. Simons, Chief of the Space Biology Branch, has always taken a very direct, personal share in the research related to the hazard of cosmic rays.

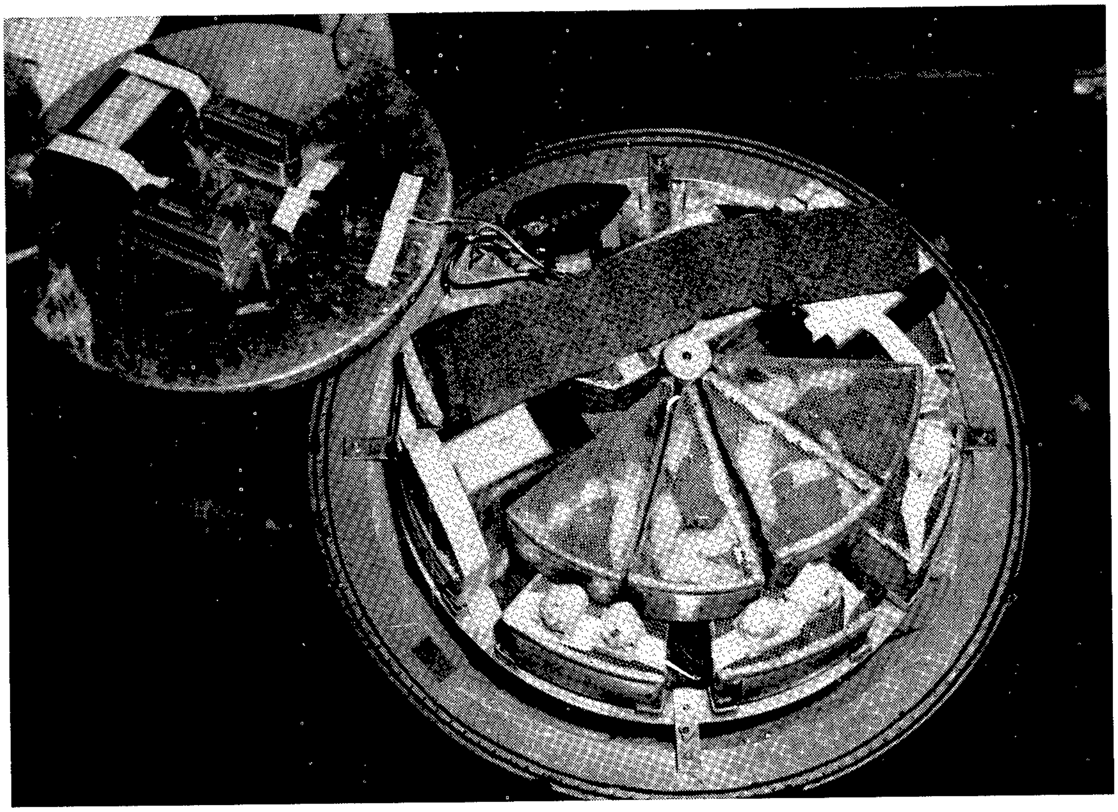
Direction of the cosmic radiation program was transferred from Wright Field to the Aeromedical Field Laboratory early in 1953, at the same time that Simons was assigned to Holloman, and at first it was the only active endeavor of his Space Biology Branch. Moreover, his arrival coincided with the general turning-point in the history of the program that has brought a sharp increase in scientific achievement from 1953 to the present.

The very first flight in the cosmic radiation program after Simons' arrival, however, indicated how easily it could still be subverted by human error. The flight began at Holloman Air Force Base on 12 February 1953 with the objective of exposing hamsters to the effects of radiation at about 90,000 feet for a period of long duration. The balloon evaded tracking crews, but the capsule landed the next day near Whiting Naval Air Station in Florida where it was promptly recovered. The naval authorities sent a teletypewriter message to the Aeromedical Field Laboratory asking what should be done with the capsule. The message was delivered six days later--a minor duration record in itself caused by unusually inefficient service at Center headquarters--whereupon a quick telephone call to Florida effected the opening of the capsule. All seven hamster passengers were still alive, although one died the next day and another was later cannibalized by his fellows.[12]

This memorable flight was followed by six launched from Vernalis Naval Air Station, California, 19-26 February 1953. These were "Moby Dick" flights designed to study high-altitude wind fields for the Air Force Cambridge Research Center by means of long-duration balloon trajectories, but in each instance the Space Biology Branch flew 600 fruit flies **(drosophila)** in sealed tubes as part of the balloon equipment. Unfortunately, the Moby Dick project called for flight plans that were too long for effective tracking. Some packages were found and returned, but exactly twelve flies out of several thousand used ever came back alive to Holloman.[13]

After three more flights from Holloman, carrying mice, flies, hamsters and dogs to the upper atmosphere, the first flight from a northern location took place on 26 March 1953. The exact site was Tillamook, Oregon, using another Moby Dick launch installation. Then another series of Holloman flights was followed by a sequence of four more northern flights in June and July from Great Falls Air Force Base, Montana. Equipment, workspace and other facilities were provided by the 1300th Air Resupply and Communications Squadron (Special), but the Holloman Balloon Branch sent north its own crew to conduct the launchings. The balloon manufacturer, Mr. Otto C. Winzen of Winzen Research, Incorporated, was present as consultant for the first Great Falls launching.[14]

The last northern flights for 1953 were launched in October and November from Pierre, South Dakota, under a contract with General Mills. The latter firm supplied the balloons this time and took full responsibility for the flight operations, using its own crews and equipment, although a number of Holloman specialists including Major Simons were also on hand.[15] This series consisted of five flights and set a precedent for the conduct of off-base flights on a contract basis, but it was the only time that General Mills successfully bid for the contract.



Aeromedical Animal Capsule Ready for Launch

Mouse Entering Container for Ride to Stratosphere

The northern flights for 1954--following more flights from Holloman chiefly to evaluate capsule techniques--were conducted under contract with Winzen Research. After one preliminary launching at Fleming Field in South Saint Paul, the main series took place at Sault Sainte Marie, Michigan, a location at fifty-seven and one-half degrees north geomagnetic latitude. Winzen supplied both balloons and launch crew, the latter headed by Mr. Ed Lewis, who has also launched propaganda balloons across the Iron Curtain in Europe. Winzen further supplied a Navion tracking aircraft, which worked along with a Holloman C-47, and two radio-equipped panel trucks that Winzen had on loan from the Navy.

Eight flights originated at Sault Sainte Marie with biological specimens ranging from radish seeds to monkeys. Two sets of monkeys were lost through technical difficulties, but the next pair flew successfully on two separate occasions. Major Simons and Lieutenant Steinmetz jointly won the United Air Lines Tuttle Award for a paper they prepared describing the methods and results of this series of flights from Sault Sainte Marie.[16]

Another six Holloman flights in the fall of 1954 and the first part of 1955 set the stage for the last northern series to date that has been devoted primarily to biological cosmic ray research. This was the series of eleven launchings from South Saint Paul and International Falls, Minnesota, which took place 18 July through 20 September 1955. Winzen Research again directed flight operations under contract, although on several occasions uninvited tracking assistance was received from jet fighters of the Air Defense Command which went aloft as a result of balloon-inspired flying saucer reports.[17]

During 1956 and 1957, the cosmic radiation program at the Air Force Missile Development Center received less emphasis. One reason is that much of the time the energies and resources of the Aeromedical Field Laboratory, and of the Space Biology Branch in particular, were absorbed in preparations for Holloman's manned balloon program, Project Man-High, which reached a climax with the record-breaking ascent of Major Simons on 19-20 August 1957. Another reason for the slackening pace in cosmic ray research is that the Human Factors Division at Headquarters, Air Research and Development Command was not sufficiently interested. It saw that limited funds were available for human factors research, and gave higher priority to other projects.

In fiscal year 1957, as a result, Task 78500 received no "in-house" operating funds at all, while any research on cosmic ray effects by outside investigators had to be funded not through Holloman but through the Air Force Office of Scientific Research. The latter negotiated only one contract, with the University of Texas. Headquarters assumed that test flights of the Man-High balloon capsule could provide whatever direct cosmic ray exposures were needed under the Texas contract and two other outside contracts that were still in effect from an earlier period.

Even during fiscal year 1957, Lieutenant Kuehn remained at his post as cosmic ray task scientist, but he could not do much more than think things over. After 1 July 1957, finally, the Aeromedical Field Laboratory got back its former right to negotiate contracts for cosmic ray research. In fact specific provision for such contracts was contained in the laboratory's new Project 7857, Research in Extreme Altitude Bio-Sciences, which had just been approved precisely as a means of sponsoring contract research. But the necessary funds were not immediately made available; and, though "in-house" activities were also authorized once more, it would be some time before the program could regain its earlier momentum.[18]

In any event, during the two calendar years 1956 and 1957 just two balloon flights were made specifically for cosmic radiation, bringing the number of such flights since the program began to a grand total of seventy-eight.* These two flights were launched from Holloman early in 1956, in large part as controls for the International Falls flights of 1955. Certain cosmic ray biological experiments were also combined with flight-testing of the Man-High capsule, although not as many as originally hoped. Finally, a series of cosmic ray experiments were combined with Major Simons' own thirty-two hour flight on 19-20 August 1957.

Two containers of **neurospora** mold were flown underneath the Man-High capsule for a study of the genetic effects of cosmic radiation, and Major Simons himself served as a subject for cosmic ray re-

*The figure may be slightly arbitrary, since it is not easy to tell whether some of the early flights were specifically for cosmic ray research; the "Moby Dick" flights, however, are definitely not included.

search (among many other things), with three track plates attached to his body as a means of monitoring cosmic ray exposure. At one point it had been decided to send up a monkey inside the capsule, too, not so much to keep Major Simons company as to provide another cosmic ray experiment. The monkey was even selected by Dr. Webb Haymaker, Chief of the Neuropathology Section, Armed Forces Institute of Pathology, and shipped from Washington, D. C., to Wright Air Development Center to take part in a final chamber test of the capsule. But at this point the monkey was firmly grounded by order of Colonel John Paul Stapp, Chief of the Aeromedical Field Laboratory.[19]

Major Simons' flight was an unqualified success, but the same cannot be said of all other balloon flights launched in recent years for research in space biology. Despite sharply improved performance as compared with the formative period from 1950 through 1952, this was still a rather unpredictable type of research. There continued to be balloon and capsule failures from time to time even after the technical innovations already described. Or, if recovery was significantly delayed, the biological subjects might die of heat prostration as temperature built up inside their capsule on the ground. Similarly, there were still some flights that were never recovered at all. As late as September 1955, one northern flight flatly refused to cut down and impacted "presumably in the northwestern Atlantic Ocean or northeastern Canada."[20] At least there is no record of an aeromedical capsule ever going all the way across the ocean, although some other Holloman balloon packages have attracted attention by landing in Europe or North Africa.[21]

One curious fact is that out of a half dozen flights made in 1952-1954, with an animal capsule expressly devised by New York University for dog passengers, not one was successful. Either the capsule itself failed or something else went wrong every time.[22] Even so, the capsule in question was not a total failure for it suggested useful innovations that were incorporated into other aeromedical capsules, and naturally many other flights that fell short of prior specifications contributed useful data of some sort.

Above all, techniques improved enough from 1953 to the present to expose a significant number of biological specimens to cosmic radiation and recover them in good shape, thus fulfilling the objective of the cosmic radiation program. Specimens flown at northern latitudes were then compared with controls flown at lower geomagnetic latitude from Holloman Air Force Base, or, as the case might be, with ground controls that were not flown at all but were exposed to environmental conditions roughly similar save in atmospheric radiation to those experienced by balloon-borne specimens. For the latter purpose, an environmental test chamber was prepared and used at the Aeromedical Field Laboratory. Even when all mammalian specimens on one flight died through loss of capsule pressure, it was necessary to reproduce in the test chamber the same extremes of pressure and temperature encountered in flight in order to have ground controls for radish seeds that had accompanied the mammalian specimens.[23]

In the case of radish seeds, scientists of the Aeromedical Field Laboratory were interested in watching their germination in order to detect possible developmental effects of cosmic radiation. They tried to perform roughly the same type of study with fertilized hen eggs only to find that hen eggs made poor test subjects.[24] The Holloman laboratory also took charge of mating the fruit flies exposed to cosmic radiation in an effort to investigate genetic effects. This branch of study was, to cite Major Simons, of "primary interest to pilots in terms of morale."[25] Yet in all the experiments performed "in house" by Holloman aeromedical scientists--including the exposure of Major Simons himself as a test specimen in August 1957--the effects of cosmic radiation have so far proven either negative or simply inconclusive.

A relatively small portion of the total research on exposed biological specimens has been performed at Holloman by laboratory personnel. Much of the research has been performed for them by academic investigators, frequently on a contract basis. As mentioned in a previous study, Dr. Berry Campbell of the University of Minnesota received an Air Force contract for neurocytological research during the early stages of the cosmic radiation program, when it was still literally a "field" activity of Wright Air Development Center. Dr. Campbell sought to examine neural tissue for cosmic ray damage, which seemed a promising approach since this tissue is non-regenerative. However, the specimens that he received for examination, from September 1951 to the end of 1953, were not very numerous and offered no conclusive evidence. All those flown before the beginning of northern flights failed even to re-

ceive significant cosmic ray exposure. Dr. Campbell also attempted to radiate hamsters with the 184-inch University of California cyclotron at Berkeley, hoping that such experiments would "serve as a model of the cosmic ray events," but this method proved unsatisfactory, apparently because of mechanical difficulties.[26]

Professor Herman B. Chase of Brown University, the second academic research scientist whose collaboration was obtained on a contract basis, was more fortunate. He began exposing mice to cosmic radiation in the fall of 1953 on the flights from Pierre, South Dakota, to study cutaneous effects. He later added guinea pigs, and all his specimens other than controls were flown from northern locations and during a period when flight techniques were improving appreciably. Professor Chase and his Brown associates were thus able to report what are probably the most clear-cut positive effects of cosmic radiation to date: a statistically significant increase in white or grey hairs on black mice and guinea pigs, apparently due to destruction of pigmentation cells by cosmic rays.[27]

Another notable research contract, in this case partly financed by the Atomic Energy Commission, provided physiological and psychological testing for the two monkeys successfully flown from Sault Sainte Marie in 1954. Supplied originally by the Wright Air Development Center, the monkeys spent over seventy hours above 82,000 feet. They were then delivered to Dr. Harry F. Harlow of the University of Wisconsin for a study lasting six months. They received the Wisconsin Appetite Test to detect any possible changes in their fondness for peanuts and raisins, and were subjected to many other tests as well, after which they went to Holloman and there remained for some time under less intensive observation. No evidence of harm from cosmic rays was ever established.[28]

Dr. Jakob A. G. Eugster of Berne, Switzerland, has been a regular, though distant, collaborator in the cosmic radiation program. One of the world pioneers in biological research concerning cosmic rays, Eugster has exposed specimens to radiation by attaching them to weather balloons in Switzerland--which is the only known instance of such research flights in recent years other than those conducted by the Holloman laboratory. He has also sent specimens across the Atlantic to be flown by the Aeromedical Field Laboratory and then returned to him for examination. Part of his research has been financed under contract with the European Office of the Air Research and Development Command. Eugster has not shipped animals from Europe, but has sent over seeds and, most exotic of all, excised pieces of animal skin and human skin (his own) which were reimplanted in their donors after being flown both at Holloman and farther north. Some of these skin segments have shown after-effects from their exposure to cosmic rays, but apparently none of a very serious nature.[29]

Dr. Wilson S. Stone of the University of Texas and Dr. A. Gib DeBusk, formerly at Texas and now with Florida State University, have shown a special interest in the genetic effects of cosmic rays. **Neurospora crassa** molds were flown on their behalf during the 1955 International Falls flights, and both reported a significant increase in the number of mutants following exposure to cosmic radiation. Subsequently both men joined the ranks of investigators agreeing to do research under contract. Dr. Stone was the lone recipient of an Office of Scientific Research contract during fiscal year 1957, when Holloman was unable to fund such research on its own. Dr. DeBusk, though his contract had technically expired by then, had the signal honor of contributing the **neurospora** samples that were attached to Major Simons' capsule on the record flight of August 1957.[30]

Another major portion of the research with test specimens exposed on Aeromedical Field Laboratory balloon flights has been accomplished or directed by scientists working for other government institutions. Dr. Webb Haymaker of the Armed Forces Institute of Pathology has continued the work of Dr. Berry Campbell on nerve tissue, in collaboration with other scientists both in the United States and abroad. He has flown live mice and guinea pigs and also various tissue cultures. Lieutenant I. J. Lebish, of the same Institute, exposed different strains of mice to cosmic rays and then studied them for radiation-induced leukemia and for effects on longevity and breeding.[31]

Dr. Paul Cibis and Dr. Hubertus Strughold of the School of Aviation Medicine exposed mice on aeromedical flights for a study of possible eye damage, and Dr. Howard Walton of Argonne National Laboratory (operated by the University of Chicago for the Atomic Energy Commission) looked for developmental aberrations in balloon-flown seeds and grasshopper eggs.[32] Mr. Robert E. McDaniel at the Army's White Sands Proving Ground, located across the integrated range from

Holloman, flew cosmic ray track plates both in rockets from the Proving Ground and on Holloman balloons.[33] Much effort has been spent developing techniques for attaching such track plates directly to biological specimens, to correlate specific cosmic ray hits with signs of damage;[34] but even when flown unattached, as in the experiments of McDaniel and others, they may help indirectly to clarify the biological significance of cosmic rays. Dr. Herman Yagoda of the National Institutes of Health has attempted an interesting middle course by mounting track plate emulsion on "a human skull padded with foam rubber to simulate soft tissue," then having this odd contraption flown by the Aeromedical Field Laboratory.[35]

This by no means exhausts the list of both government and academic researchers who have participated one way or another in the Aeromedical Field Laboratory cosmic radiation flights. In some cases a flight has been conducted for the primary purpose of assisting one of these researchers, while in other cases they have sent along "hitchhike" loads not related to the primary purpose of a flight but still promising a contribution to knowledge on cosmic rays and their biological effects. Hitchhike loads have even included a number of experimental altimeters, which were welcomed by Major Simons and his associates in view of the benefit to be gained for research ballooning generally through the development of more accurate altitude measurements.[36] Some of the off-base collaborators have also made valuable contributions as advisers, in the general management of the cosmic radiation program, and some have turned up in person to take part in the actual flight operations. Dr. Haymaker has even composed a short article, "Operation Stratomouse,"[37] giving a lively picture of his own direct participation in the 1955 International Falls flights.

The net result of so much collaborative effort has been to turn up relatively few positive signs of cosmic ray effects. Aside from Professor Chase's success in turning mice and guinea pigs prematurely gray, the skin effects produced by Eugster, and the **neurospora** mutants, which have all been mentioned already, there were some indications of development aberrations among seeds and grasshopper eggs exposed to cosmic radiation for different researchers in 1954 and 1955. Dr. Haymaker also reports what may have been a lesion inflicted by cosmic radiation upon one guinea pig exposed during a Man-High capsule test in November 1956.[38]

There is a chance that additional cosmic radiation effects will be noted when analysis of all experiments conducted so far is completed, and some of the observed effects are still poorly understood. Negative results are often highly inconclusive because of inadequate sampling or exposure. Yet, even with these qualifications, the experimental results have been encouraging. In the case of neural tissue, Major Simons tentatively concluded that "nerve cells either suffer minimal damage. . .or show delayed changes only."[39] As for hair-graying, it is certainly a tolerable after-effect; and the genetic effects, while raising a possibility of increased mutations among descendants of space travelers, did not pose any immediate social problem. In general, it could be said that there was some hazard in cosmic rays, as in most everything else, but the risk was not so great as to offset the positive advantages of exploring the vertical frontier.

To be sure, much remains to be done in the way of cosmic radiation studies. For proper interpretation of observed effects, some of the cosmic ray experiments should be conducted again with track plates directly attached to the biological specimens. Still longer exposures are likewise in order, especially at the altitude range of 125,000 to 135,000 feet. It does not appear that a significant increase in cosmic ray effects would be found by going much higher than that, which is fortunate since the balloon as a research vehicle must have at least some air in which to float. Animal flights currently planned for the summer of 1958 will of course help to meet these requirements.[40] Additional manned flights, too, are necessary before a final assessment of the cosmic radiation problem can be made. In this respect Major Simons' Man-High ascent, which involved much more than cosmic ray research, was only a beginning. Nevertheless, the progress already made in cosmic radiation studies through the efforts of the Aeromedical Field Laboratory forms one of the major achievements of space biology research in recent years.

3. Project Man-High

Another area of broad achievement in space biology research at the Air Force Missile Development Center--even more dramatic in many ways than the program of cosmic radiation studies--has been the actual placing of human beings into a non-artificial space-equivalent environment. As balloon techniques steadily improved, and as the possible dangers from cosmic rays were brought more and more into

proper perspective by the animal flights, it was only natural for the Aeromedical Field Laboratory to consider manned balloon ascents. These would be an entirely logical outgrowth of the earlier cosmic radiation flights. Manned flights, however, would combine still other advantages. There was a broad range of upper atmospheric investigations that could best be handled by a human observer at high altitude. There was also an urgent need for improvements in manned capsule or sealed-cabin environments, not only for the design of high-performance aircraft--including experimental rocket planes--but also as a step toward a manned satellite and true space flight. A manned balloon flight was one of the best ways of testing such improvements and of finding out if man is capable, physically and psychologically, of extended travel at space-equivalent altitude.

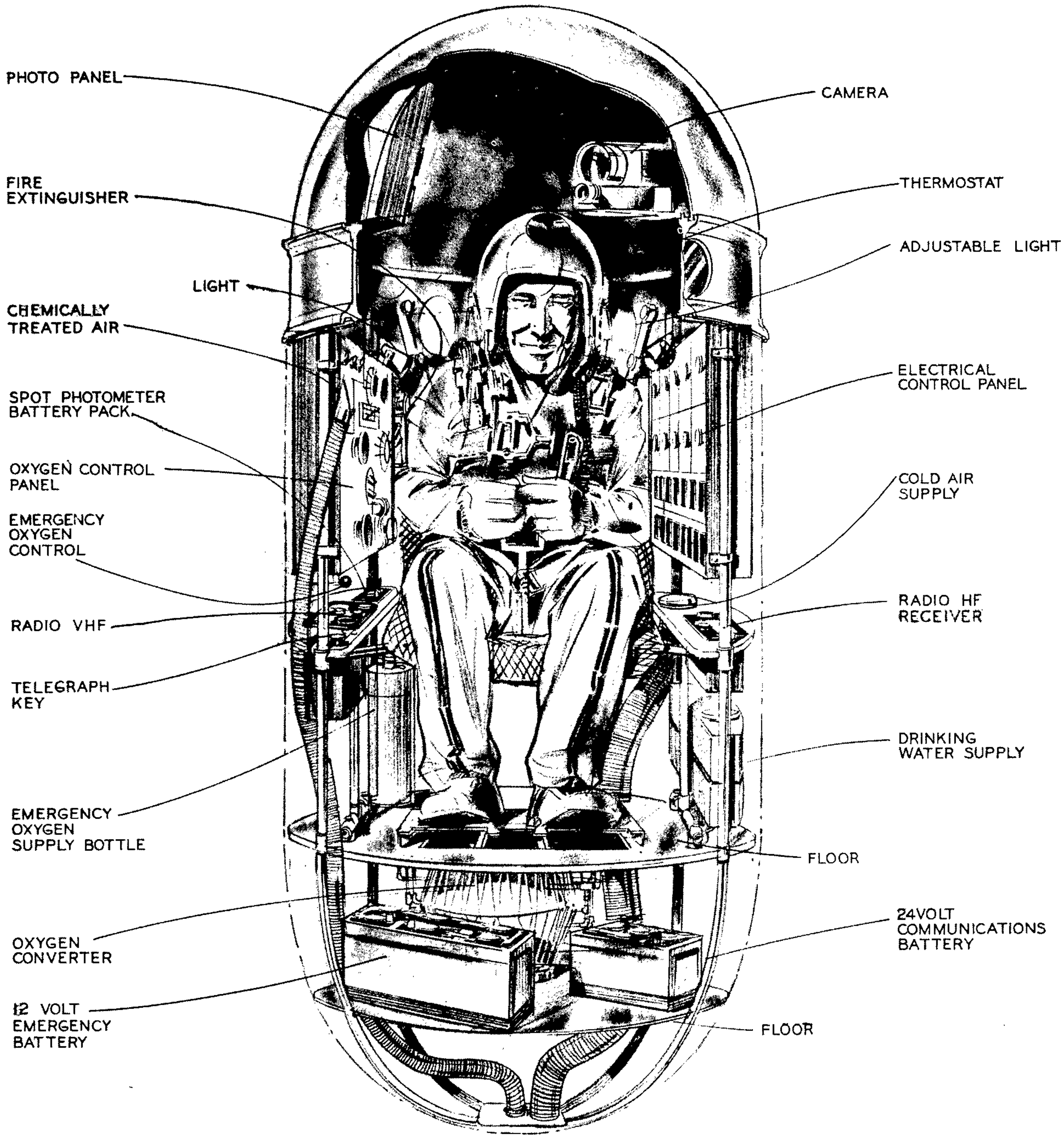
Concrete consideration of a manned flight began in mid-1955. Colonel John Paul Stapp and Major David G. Simons of the Holloman Aeromedical Field Laboratory, and Mr. Otto C. Winzen, head of Winzen Research, Incorporated, discussed the prospect at length, the latter two taking time out from balloon flights they were conducting in northern Minnesota at the time. All agreed that a twenty-four-hour manned flight at about 115,000 feet was feasible. At the end of August 1955, Colonel John Talbot, Chief of the Human Factors Division, Headquarters, Air Research and Development Command, gave tentative approval to the project.[41]

As conceived by Colonel Stapp and Major Simons, the Holloman manned-balloon project would avoid as far as possible mere duplication of work being accomplished elsewhere. Colonel Stapp observed that they did not intend either to "trespass on other people's research territory" or to "have track meets in the sky."[42] There was, of course, no comparison between a high-altitude manned balloon flight and occasional flights to similar altitude by experimental aircraft, since the latter can remain there only briefly, not long enough for intensive experimentation. The Navy had its own program for high-altitude research with manned balloons, and a man-carrying gondola "Stratolab" already in existence. But the Navy program had been until recently in a state of suspended animation; the Navy did not plan to go as high; and its research objectives were less broad than those the Aeromedical Field Laboratory had in mind.[43]

Nor, finally, did the Holloman scientists have any desire to compete with the manned-balloon program that formed part of Project 7218, Biophysics of Escape, an activity of Wright Air Development Center's Aero Medical Laboratory. At least for the present, that program was not really concerned with space biology. It was interested mainly in high-altitude escape problems, and it had been plagued with difficulties that made uncertain just when its first actual manned ascent would take place. The Wright Field program was supposed ultimately to produce another balloon-borne research laboratory, and in fact there was room for several of these. But when and if the Aero Medical Laboratory set to work on this final stage of its program, it would be able to draw on experience already accumulated at Holloman without going through all the same experimental steps. Meanwhile, the Holloman program could also profit from knowledge and experience available at Wright Field, especially in the field of high-altitude parachute systems.[44]

In its early stages, the Holloman manned-balloon program was called Project Daedalus, a name later changed to Man-High. It was also referred to, originally, as "the manned balloon phase of Task 500," that is, of cosmic radiation studies. Before long--January 1956 at the latest--command headquarters decided that a manned flight could not be justified and funded purely under this heading, but, as already noted, there was no lack of alternative justifications. Planning and preparations went right on, chiefly under the auspices of Task 78516, Environmental Control in Sealed Cabins, which was formally established as a separate task in the latter part of 1955. Captain Druey P. Parks and Captain Erwin R. Archibald have both served as task scientists, either separately or together. At present the position is held by Captain Archibald. However, Major Simons himself has always been the primary project officer for Daedalus/Man-High, with Captains Parks and Archibald as his deputies.[45]

Assigning the manned balloon program primarily to Task 78516 was completely appropriate, if not almost inevitable, since the most complex problem to be faced was the design and fabrication of a sealed capsule suitable for high-altitude flight for a day or more. The successful development of Aeromedical Field Laboratory animal capsules pointed the way, and so did the Navy's "Stratolab," which had been designed largely by Mr. Winzen. Yet specifications for the proposed capsule



383428 -- Schematic artist's drawing of the USAF-Winzen Research Inc. MAN-HIGH gondola showing location of internal instruments and components. Pilot normally breathes the oxygen-helium capsule atmosphere. Equivalent cabin altitude can be selected on the panel. The MAN-HIGH capsule is a minimum weight vehicle for one-man flights to altitudes in excess of 100,000 feet and for durations in excess of 24 hours permitting night and day observations and studies of human factors in space medicine. The Winzen Research MAN-HIGH capsule is the first true space cabin and will serve as a research vehicle for the study of requirements for manned space flight.

(Drawing and Caption by Winzen Research)

were more complex than for either animal capsules or "Stratolab," and even greater precision was required. Accordingly, a special contract was drawn up for the design, fabrication, and maintenance or modification "during the flight test period" of the needed balloon-capsule system. The contract was awarded to Winzen Research, Incorporated of Minneapolis, effective 9 November 1955.[46]

This same contract had been sought by General Mills, the other leading balloon manufacturer, and unfortunately some hard feelings arose when Winzen won the assignment. It was necessary for Holloman's Directorate of Procurement, the contracting agency, to explain that no aspersion was intended upon the technical qualifications of the General Mills organization, but that the other proposal showed closer attention to details and in general what seemed to be a superior approach in its specific suggestions for the undertaking. Numerous supplemental agreements were added to the contract from time to time, making detailed changes in the capsule plans and expanding the scope of the required flight-testing. One such agreement provided that Winzen Research should be responsible for launch, tracking, and recovery of both the test flights and the definitive manned flight.[47]

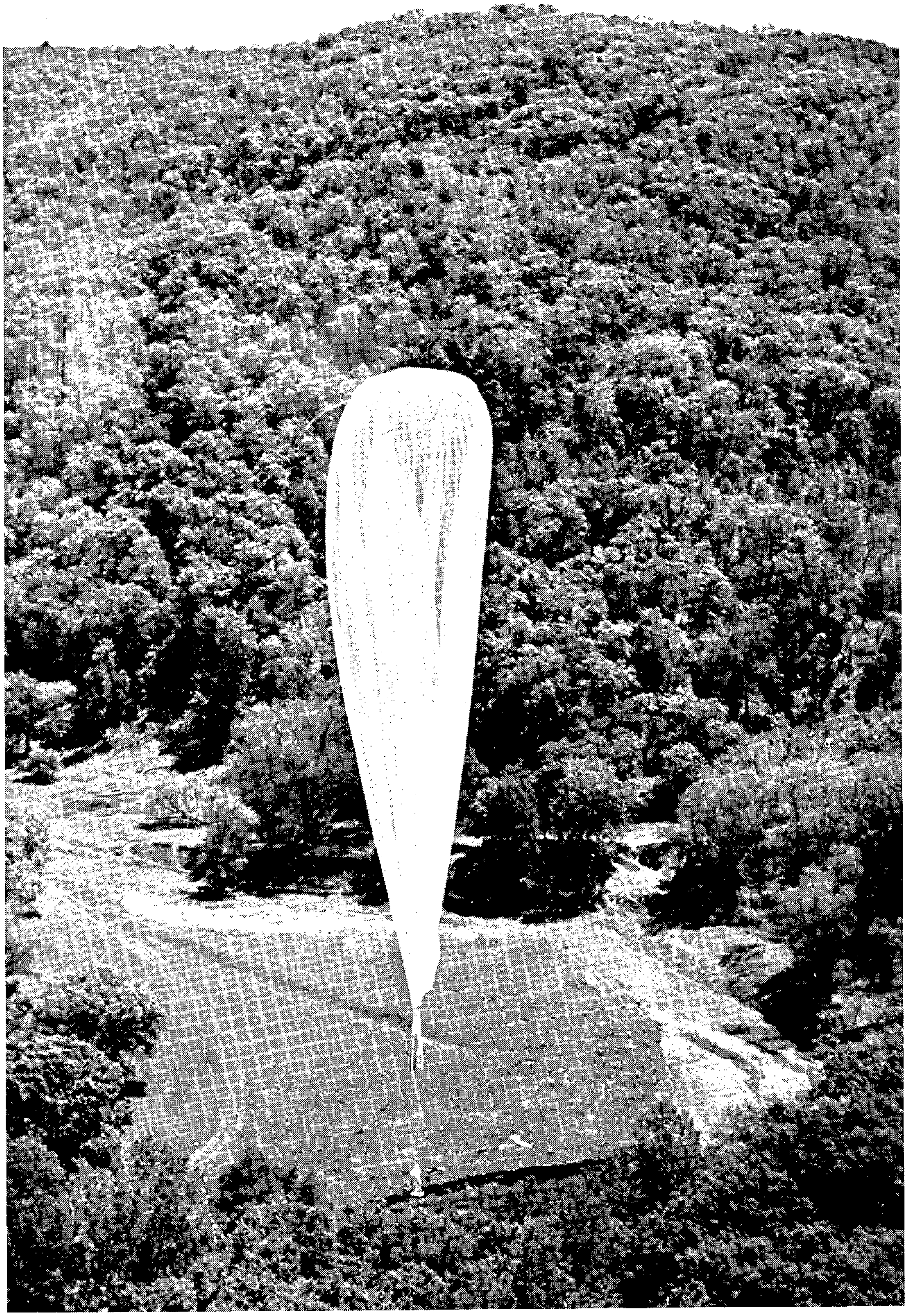
The original contract with Winzen Research called for completion of the capsule by 31 January 1956, and completion of flight-testing on or before 15 March. The definitive flight had originally been set for the spring of 1956.[48] Like most tentative deadlines, all these proved overly optimistic. Since funds were short for the command human factors program, Daedalus/Man-High had to take whatever snatches and installments were available, even if it meant stretching out deadlines. Command officials gave their final approval to the project in March 1956, on the basis of revised justification demoting cosmic ray research to a secondary role; but approval in itself did not pay any bills, and funds were thus a continuing problem. Meanwhile, Captain Edward G. Sperry, co-holder of the world's high-altitude parachute jump record, became coordinator for the project at Headquarters, Air Research and Development Command.[49]

Coordination was also effected with Wright Air Development Center, where officers of Project 7218 offered some criticism of the plans on technical grounds. There also appears to have been some feeling among people at Wright Field (initially, at least) that the Holloman manned-balloon program represented a duplication of effort with their own. In practice, however, duplication was kept to a minimum, and the Aero Medical Laboratory at Wright Field made a number of valuable suggestions and contributions to the program. In addition, Air Research and Development Command specifically assigned the responsibility for final approval of the personal and capsule-recovery parachute equipment to specialists of Wright Air Development Center's Equipment Laboratory.[50]

Coordination was required with still other agencies and institutions, but naturally the greatest amount of time and effort went into development and testing of the balloon-capsule system itself. As the work progressed, officials of Winzen Research and of the Aeromedical Field Laboratory incorporated additional mechanical improvements and safety features. Then, too, as already noted, provision was later made for more testing than originally specified. The growing scale and complexity of the operation is graphically reflected in the various revisions of estimated contract cost, which ultimately rose from the rough figure of $29,950 used in November 1955 to $235,590.30 (including fixed fee of $3300). To be sure, these figures are not strictly comparable, one obvious difference being that the original estimate was not intended to cover any launch, tracking, and recovery services. Also the contract costs would have been less--Major Simons guesses about $75,000 less--if funds had always been available just when needed. Over and above the contract figure, Winzen Research agreed to assume $14,178 more from company resources.[51]

Compared to the price of an intercontinental missile, a manned-balloon project was still relatively low-cost research. It was expensive mainly in comparison with the earlier animal flights, whose cost when launched at Holloman was estimated in March 1954 at between $5,000 and $10,000 each.[52] The latter estimate is for the total cost including Air Force manhours, whereas the Winzen contract figures naturally cover expenditures only by the private firm.

The Man-High capsule as it finally emerged from so much intensive research and development was an aluminum-alloy structure eight feet in height. It had six portholes, one of them equipped with a mirror system enabling the pilot to see either above or below the capsule. Instruments for recording a wide variety of scientific data were on an inside photo



Man-High (I) Flight About to End in Minnesota Brook

panel, with a camera mounted opposite to photograph the panel at set intervals throughout the flight. A special microphone was included, designed to monitor the pilot's heart beat. There was also a magnetic tape recorder with which he would preserve his own visual and psychological impressions.

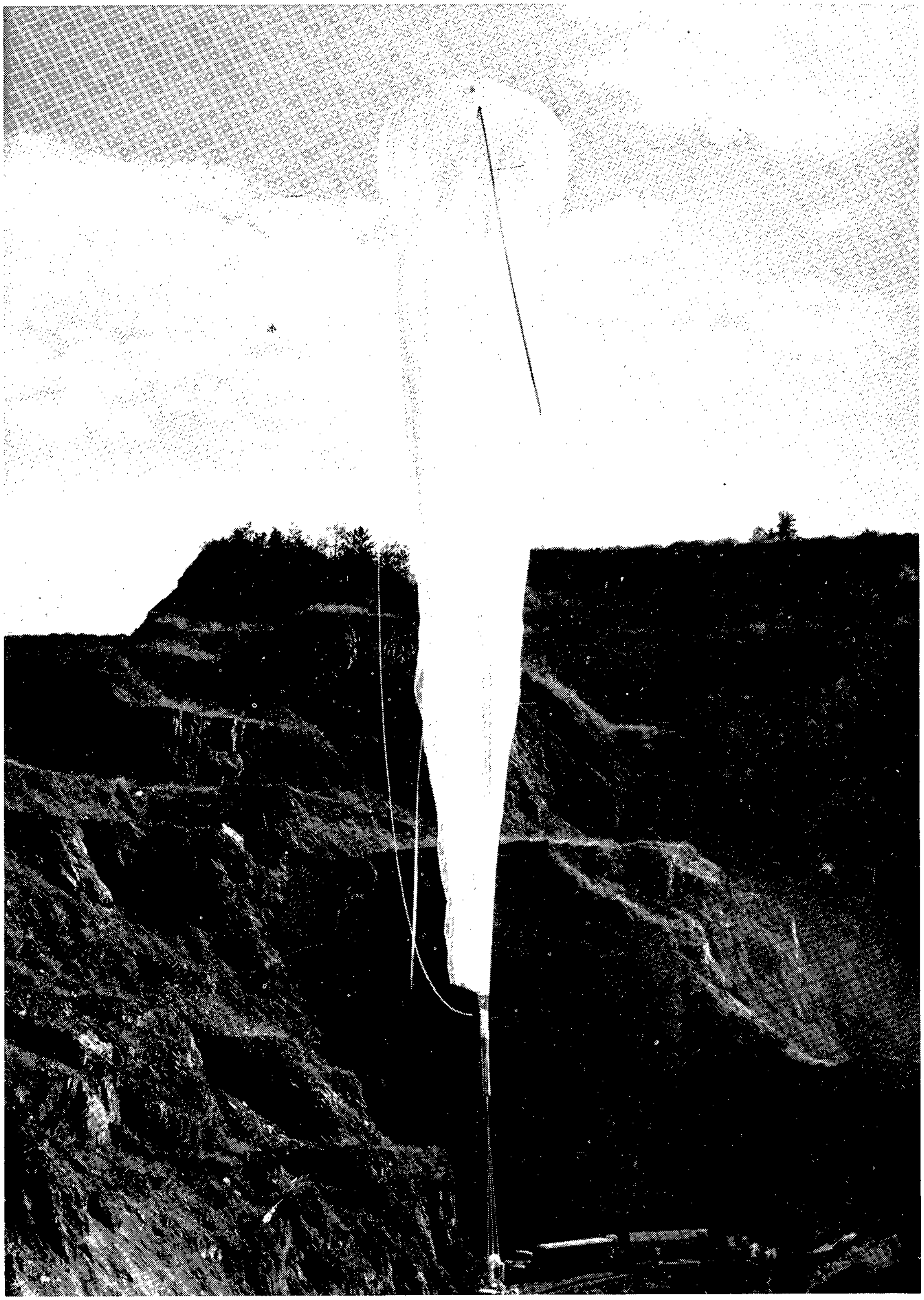
All told, there were so many electric components on board that the heat they gave off, plus the pilot's body heat, made a separate heating system unnecessary. Daytime cooling was still needed, and was provided by basically the same boiling-water method used on earlier animal flights. The sealed cabin atmosphere was a newly-devised oxygen-helium-nitrogen combination. The pilot had different emergency oxygen systems to fall back on, and a similar array of safety features was available for possible emergency descent. Under normal conditions, the pilot would come down by valving gas out of the balloon. If this method should fail (or if the balloon itself should ever fail) the capsule could separate from the balloon and descend by its own cargo parachute. Should the capsule parachute fail, the pilot might still bail out with his high-altitude personal parachute.[53]

The required flight-testing of this balloon-capsule system was of course one of the most time-consuming and expensive aspects of the entire undertaking. A single test flight did not take long, but preparations were another matter, and weather often caused frustrating delays. In order to test the capsule temperature control and atmosphere systems, preliminary flights were launched carrying a sufficient number of small animal passengers to approximate one human occupant. The animals served, secondarily, as cosmic radiation subjects. Other balloon and gondola equipment was also checked out during the flight-test phase, and on one flight a dummy drop was staged from high altitude to test the pilot's personal parachute system. All this was in addition to assorted ground tests. There were even water tests of the Man-High capsule to make sure that it could, if necessary, execute a safe water landing.[54]

The first manned ascent--and final test flight--was held on 2 June 1957. It might have been expected that the first human passenger would be Major Simons, who was eagerly awaiting the chance to do himself what he had been sending mice and guinea pigs to do for several years. However, Major Simons was held in reserve for the full-scale research flight. For the preliminary manned test flight, Colonel Stapp chose Captain Joseph W. Kittinger, a young but highly experienced jet pilot assigned to the Center's Flight Test Division. Since Kittinger was a test pilot by profession, Colonel Stapp felt he would be ideally suited for the assignment. Even so, the captain had to take months of additional training for this one flight. Among other things, he took enough parachute training to qualify officially as a paratrooper; had a claustrophobia test; and practiced ballooning in low-altitude, open-gondola flights, using the "Sky Car" developed specifically for low-altitude balloon flights by Winzen Research, Incorporated. These "Sky Car" flights were also used to check out certain items of equipment.[55]

At 0623 hours on 2 June, Captain Kittinger's Man-High (I) flight began, from Fleming Field, South Saint Paul, Minnesota. A Winzen crew conducted the launching, as provided by the Man-High contract, in collaboration with members of the Aeromedical Field Laboratory and other units at Holloman. The 475th Air Base Squadron, Minneapolis, provided additional helicopter support. The vehicle was a two-million-cubic-foot plastic balloon, 172.6 feet in diameter, which quickly reached the planned ceiling altitude of 95,000 feet, setting a new record for manned balloons. Test specifications called for a twelve-hour flight. However, because of an oxygen leak (due to an improperly connected valve) and also certain communications difficulties, Colonel Stapp and Mr. Winzen decided that Captain Kittinger should come down after not quite two hours at altitude. The balloon pilot was not happy with the decision, replying by radio, "Come and get me." But he did come down, and landed successfully at 1257 hours none the worse for his experience.[56]

The capsule was pronounced sound, despite the minor difficulties that had arisen. Nevertheless, before the next flight it was given one final test in a high-altitude pressure chamber at Wright Air Development Center, after which certain minor modifications but no basic design changes were made.[57] Special instrumentation was added as required by the Fédération Aéronautique Internationale for the purpose of establishing an official world's altitude record; this had not been done for the June flight, which accordingly set an "unofficial" record only. The capsule was also fitted out with a five-inch telescope for astronomical observations, another noteworthy new item of equipment. Indeed, the Man-High capsule was now more than ever "a floating scientific laboratory."



Man-High (II) Launching, 19 August 1957

At least twenty-five distinct scientific experiments were to be performed on the definitive manned flight, involving everything from physical data on the upper atmosphere to whatever psychological reactions the pilot might wish to transcribe on the capsule's tape recorder.[58]

The most important single scientific instrument was Major Simons himself, who meanwhile had received his special training for the flight. He took only one parachute jump, but otherwise the process was much the same as it had been for Captain Kittinger. Like Kittinger, Major Simons was also subjected to complete physical examination in order to establish a basis of comparison with his post-flight physical condition. This included blood and urine samples--to be compared with post-flight samples--as part of a special study of adrenal response to stress. However, Major Simons was bled for at least one more experiment than Kittinger, because this time special arrangements had been made with Dr. R. Lowry Dobson of the University of California to investigate the possible appearance of bilobed lymphocytes in the pilot's blood as a result of cosmic radiation. This was a phenomenon that had already been noted in the blood of workers exposed to low levels of ionizing radiation at the University of California cyclotron.[59]

The actual launch did not take place until 19 August, but the final gathering of men and equipment began some days earlier. Preparations were even more elaborate than for the Kittinger flight. The Army sent two helicopters with their crews to aid in tracking and recovery; and since the Navy not only supplied helium for the balloon but made available (as often before) the ground vehicles and other equipment that it had assigned to Winzen Research for use with naval research flights, the project became a truly interservice affair. The aircraft contingent was completed with a Navion belonging to Winzen Research, two Air Force helicopters borrowed locally, and two C-47's from Holloman. Captain Kittinger returned to Minnesota as coordinator of air support operations, although he did not remain for the flight itself. His place was taken on 19 August by Major Hubert S. Williams, at that time Commander of Holloman's 6580th Field Maintenance Squadron.[60]

The Aeromedical Field Laboratory sent a large contingent of officers and enlisted men, headed by Colonel Stapp in the role of flight surgeon. He was to monitor Major Simons' physical condition before, during, and after the flight. Captain Parks and Captain Archibald were both on hand as assistant Man-High project officers. Lieutenant Kuehn as cosmic ray task scientist came along to care for the **neurospora** and track plates that were to accompany the capsule. Lieutenant Colonel John W. McCurdy, Information Services Officer at Holloman, came to take charge of press and public relations, in collaboration with Major Kenneth E. Grine from Headquarters, Air Research and Development Command and Mr. Joseph C. Groth, Jr., of Winzen Research. The Holloman Balloon Branch sent Mr. Bernard D. Gildenberg, Chief of its Technical Support Section, to act as meteorologist, and Master Sergeant Nabor Martinez, a communications specialist. Even one of the Center historians arrived on the scene, to record history as it happened.[61]

From Wright Field came Lieutenant Colonel Rufus Hessberg, Chief of the Biophysics Branch, Aero Medical Laboratory, whose special mission was to ride in one of the tracking planes and be on hand as paramedic in any case of emergency. The 1352nd Motion Picture Squadron, Lookout Mountain Laboratory, California, sent a camera crew; and command headquarters sent not only Major Grine but also Major E. F. Smith with a band of six air policemen. The function of the latter was to guide project people, reporters, and very important persons to their assigned stations at the launch site, and to control any passers-by who might catch sight of the launch operations and stop to look.[62]

The exact site chosen for the launch was the 425-foot open pit of an iron mine outside Crosby, Minnesota, belonging to the M. A. Hanna Company. The pit-launch method afforded protection from winds, which particularly was necessary because of the greater size of the balloon used on this flight. To be exact, the balloon had a capacity of over three million cubic feet and was 200.2 feet in diameter when completely expanded by gas at floating altitude. Its total height at the time of inflation (including capsule and suspension system) was 350 feet.[63]

Among the first to arrive at Crosby were Major Smith and his air police, who startled local citizens when they were deposited by helicopter in the middle of the town park the afternoon of 15 August. The Winzen launch crew arrived the same day, since it was hoped originally to start the flight on the morning of 16 August. Unfortunately, it was postponed twice because of predicted bad weather, but for 19 August the outlook seemed favorable.

August the outlook seemed favorable. Major Simons entered his capsule late the night before at the Winzen plant in Minneapolis. He was sealed in and at once began pre-breathing of the special capsule atmosphere, which served to remove excess nitrogen from his bloodstream and thus gave protection against an attack of the "bends" in case emergency decompression should occur at high altitude. After a final check at the plant established that equipment was in working order, the capsule with Simons in it was piled on a truck and began the trip to Crosby, arriving shortly before daybreak.

The launch was delayed again at the last minute when a segment of reefing sleeve failed to come off and formed a band around the neck of the balloon. Mrs. Vera Winzen climbed a ladder held by guy wires and cut the band. Finally, at 0922 hours, the balloon took off and rose rapidly until after two hours and eighteen minutes it reached floating altitude of about 100,000 feet. Peak altitude for the flight was 102,000 feet, a new record but less than the 115,000 mentioned at the inception of the Man-High project. Additional experiments, equipment, and ballast had all added to the weight of the balloon-capsule system and correspondingly lowered its altitude capability.[64]

The balloon drifted slowly westward during the day, but began to sink as the helium gas cooled after sundown. Indeed, it sank more than expected because unforeseen stormy weather cut off the reflected heat of the earth. Early in the morning of 20 August, the balloon was caught in a downdraft and fell to about 70,000 feet. At that point Major Simons found himself directly over a raging thunderstorm--something that had never before been known to occur at such an elevation. Accordingly, he dropped ballast to get out of danger, and soon after sunrise was again near ceiling altitude.[65]

The flight was originally expected to drift westward to the area of Miles City, Montana, but movement was slower than anticipated and the balloon never got beyond the eastern part of the Dakotas. The flight was supposed to terminate in approximately twenty-four hours, but this did not happen either. It dragged on almost a half day longer, as Major Simons in his balloon capsule and tracking parties on the ground looked for a suitable opening in the clouds through which to descend. The capsule served as a floating weather station and, in general, Major Simons' own weather observations during the flight were more accurate than any data available below.

The delay in ending the flight led to several problems in capsule environment. The effectiveness of chemicals in the air regeneration system began to decline, carbon dioxide was not absorbed fast enough, and at regular intervals Major Simons had to use a face mask for breathing. With power supply also running low, it was necessary to cut off the capsule cooling system, and temperature rose to eighty-four degrees. This was extremely uncomfortable when clad in a pressure suit, which Simons was wearing for any emergency. Fortunately, in the early afternoon Simons was able to begin a steady rate of descent. He landed at 1732 hours, in an alfalfa field in northeast South Dakota, and was immediately stuck with a hypodermic needle for another blood sample. The flight had lasted thirty-two hours and ten minutes, but Simons had actually been forty-four hours in the capsule, including the time spent in it before launch. As Mr. Winzen was quick to point out, this was longer than the time spent by Charles A. Lindberg in the first solo flight over the Atlantic.[66]

Though tired, having had only brief snatches of sleep, Major Simons emerged from the ordeal in good shape. He had a slight abrasion on his neck from the tight pressure suit, but if he suffered any serious ill effects they were slow in appearing. Colonel Stapp therefore concluded, "Human performance in an environment equivalent to space is now known to be possible."[67] The full, detailed scientific results of the flight were not immediately available, as it would take time to analyze and interpret all the data obtained. The most important information immediately available, other than the mere fact that the flight proved feasible without apparent harm to the subject, was what Simons personally observed and reported--either on tape or by radio during the flight, or in discussion after it.

Simons caught the attention of the press with his observation that the stars did not twinkle, and much was then said and written about having to revise nursery rhymes. Major Simons was in fact greatly interested in his visual observations of the sky at high altitude, in which he displayed latent poetic qualities as well as keen scientific insight. At one point he recorded on the capsule tape his impression of "a very dark foreboding blue that grades off into a slight gray," and he was delighted by the spectacle of sunrise and sunset at the top of the earth's atmosphere.[68]

For their part in the success of Project Man-High, both Major Simons and Captain Kittinger received the Distinguished Flying Cross. Major Simons received the award directly from Lieutenant General Samuel E. Anderson, Commander of the Air Research and Development Command, on 24 August 1957. Captain Kittinger received his award shortly afterward.[69] Both men also received a sudden wave of national acclaim and recognition. The tribute accorded to Major Simons, in particular, was comparable to that which greeted Colonel Stapp after his series of rides in 1954 on the Holloman high-speed track.

In all the excitement over the Man-High flights, however, the continuing research efforts on Task 78516, Environmental Control in Sealed Cabins, should not be overlooked. This one subdivision of Project 7851 provided the main technical justification for Man-High, but the task was not established purely for the sake of any one or two manned balloons. Under the immediate direction of Captain Archibald as task scientist, the task program touches on problems that are important for all types of manned vehicles traveling at extreme altitude or in space. It includes long-term research on claustrophobia and related problems, using (among other things) a simulated capsule mock-up at Holloman; adrenal response to stress; physiological effects of inert gases, to determine the best composition for sealed cabin atmospheres; and flammability problems, again in relation to the choice of sealed cabin atmospheres.

The Man-High project naturally accumulated experimental data on all four of these major problem areas, while at the same time research already accomplished by Task 78516 made an important contribution to the success of the Man-High flights. The same close interplay between particular manned ascents and long-term studies of sealed cabin environment is expected in future flight programs. Meanwhile, a contract investigation on inert gases has been entrusted to Dr. S. F. Cook of the University of California at Berkeley, and a research contract on adrenal response to stress is being established.[70]

Moreover, it was clear that the success of Man-High opened up important new opportunities for high-altitude research. By the end of 1957, therefore, Colonel Stapp, Major Simons, and their colleagues were engaged in detailed negotiations with higher headquarters over the exact steps to be taken next. The prospects included both new flights with the existing Man-High capsule, which was perfectly reusable, and the development of even bigger and better "floating scientific laboratories." As early as April 1957, Winzen Research, Incorporated submitted an "unsolicited proposal" for a balloon-borne "Satelorb" research platform capable of week-long flights with five or more men at 100,000 feet. This would have the great advantage over a one-man capsule of permitting individual specialization on balloon piloting and on different research functions.[71] A two-man version of the Man-High capsule, with room for a pilot and a full-time scientific observer, was another alternative less elaborate than "Satelorb" but easier to obtain on short notice.[72] And, of course, the ultimate outgrowth of the manned balloon capsule could be only one thing: a manned satellite.

Whenever the United States achieves the manned satellite--or human flight still farther into space--it will be no exaggeration to say that a significant portion of the preliminary work has been accomplished by the Air Force Missile Development Center. Nor has the Center's contribution been solely in the areas of cosmic ray research and high-altitude capsule development; as indicated at the outset, contributions in other fields will be discussed in later studies. Truly, the period from 1953 through 1957 was one of major advances in space biology research both for the Aeromedical Field Laboratory and for the entire Air Force Missile Development Center.

NOTES

1. **The Beginnings of Research in Space Biology at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946-1952** (Holloman AFB: AFMDC Historical Office, January 1958).

2. Maj. David G. Simons, **Stratosphere Balloon Techniques for Exposing Living Specimens to Primary Cosmic Ray Particles** (HADC Technical Report 54-16, November 1954), pp. 1-2.

3. **Ibid.**, pp. 4, 7-9, 27, 39, 42-43, 50, 54; Information Services Office, HADC, news release on balloon operations, about 1 November 1954.

4. Simons, **Stratosphere Balloon Techniques,** pp. 8, 54-55; "Major FY 54 Accomplishment; Improved tracking and recovery techniques for high altitude balloon research," incl. 10 to DF, Lt. Col. Wilbur D. Pritchard, Cmdr., 6580th Test Sq. (Special), to Plans and Programs Division, DCS/O, HADC, subj.: "Summary Letter, FY 54," 30 June 1954.

5. Maj. David G. Simons, **Military Aspects of Observed Biological Effects of Cosmic Ray Particles** (HAFB, June 1956), p. 7; Simons, **Stratosphere Balloon Techniques,** pp. 41-42, 57.

6. Maj. David G. Simons and Lt. Druey P. Parks, "Improved Techniques for Exposing Animals to Primary Cosmic Ray Particles," **Journal of Aviation Medicine,** Vol. 47, p. 318 (August 1956).

7. **Beginnings of Research in Space Biology,** p. 20; Bernard D. Gildenberg, **Development of Shroud Inflation Technique for Plastic Balloons** (HADC Technical Note 54-4), April 1954, and **Crane Launch Technique for Polyethylene Balloons** (HADC Technical Note 57-3); interview, Mr. Bernard D. Gildenberg, Chief, Technical Support Section, Balloon Branch, by Dr. David Bushnell, AFMDC Historian, 30 September 1957.

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10. Maj. David G. Simons and Lt. C. H. Steinmetz, "The 1954 Aeromedical Field Laboratory Balloon Flights, Physiological and Radiobiological Aspects," **Journal of Aviation Medicine,** Vol. 27, pp. 105-106 (April 1956).

11. Simons, **Stratosphere Balloon Techniques,** p. 4; Management Report (ARDC Form 111), Human Factors of Space Flight, 1 October 1955.

12. Simons, **Stratosphere Balloon Techniques,** pp. 19-24; interview, Maj. David G. Simons, Chief, Space Biology Branch, by Dr. Bushnell, 13 December 1957.

13. Simons, **Stratosphere Balloon Techniques,** pp. 24-25; interview, Mr. Gildenberg by Dr. Bushnell, 18 September 1957.

14. Simons, **Stratosphere Balloon Techniques,** pp. 25-38.

15. **Ibid.,** pp. 40-49.

16. Simons and Steinmetz, "The 1954 Aeromedical Field Laboratory Balloon Flights," **Journal of Aviation Medicine,** Vol. 27, pp. 100-110; Simons and Steinmetz, **Physiological and Radiobiological Aspects of the 1954 Aeromedical Field Laboratory Balloon Flights** (HAFB, n.d.), p. 13; Dr. Webb Haymaker, "Operation Stratomouse," **Military Medicine,** Vol. 119, p. 154 (September 1956); Lt. Charles H. Steinmetz, **Experimental Material Flown on Aeromedical Field Laboratory Balloon Flights 46 Through 71** (HADC Technical Note 56-2), p. 7; folder on Aeromedical Field Laboratory Flight 45, in Space Biology Branch files; Aeromedical Field Laboratory, "Historical Data. . . 1 April through 30 June 1957," p. 11.

17. Haymaker, "Operation Stratomouse," **Military Medicine,** Vol. 119, pp. 151-171; Steinmetz, **Experimental Material,** pp. 1, 11.

18. Interviews, Lt. Harold H. Kuehn, Task Scientist, Radiation Hazards, by Dr. Bushnell, 27 November and 2 December 1957; interview, Maj. Simons by Dr. Bushnell, 14 February 1958; Management Report (ARDC Form 111), Task 78500 - Radiation Hazards, 28 October 1957. Actually, the refusal of headquarters to let Holloman negotiate cosmic ray research contracts antedated the start of fiscal year 1957 by several months. See TWX, Hq., ARDC, to Cmdr., HADC, subj.: [Disapproval of Contract Proposal], March 1956.

19. Interview, Lt. Kuehn by Dr. Bushnell, 27 November 1957; **Test Report on AMFL Balloon Flight 72A,** 23 April 1956; **Test Report on AMFL Balloon Flight 73,** 17 May 1956; Aeromedical Field Laboratory, "Historical Data. . . 1 April through 30 June 1957," p. 9 and "Historical Data . . . 1 July through 30 September 1957," p. 7.

20. **Test Report on AMFL Balloon Flights 67, 68, 69, 70, and 71,** 6 October 1955.

21. Cf. **Alamogordo News,** 26 April 1951 and **Alamogordo Daily News,** 31 August 1956.

22. Simons, **Stratosphere Balloon Techniques,** pp. 19, 25-26, 29-31, 38-40, 57-59; folder on Aeromedical

Field Laboratory Flight 43, in Space Biology Branch files; interview, Capt. Druey P. Parks, R & D Staff Assistant, by Dr. Bushnell, 4 December 1957.

23. Sgt. William J. Longmore, **Preparation of Control Specimens for the 1954 Aero Medical Field Laboratory Balloon Flights** (HADC Technical Note 55-6, May 1955). The ideal method would have been to include non-radiated controls in the same capsule as the exposed specimens, but shield them against cosmic rays; however, the weight of shielding would have been prohibitive.

24. Simons, **Military Aspects of Observed Biological Effects of Cosmic Ray Particles,** p. 15; Steinmetz, **Experimental Material,** p. 4.

25. Simons, **Military Aspects,** p. 10. See also Lt. C.H. Steinmetz and Sgt. Wayne Lamke, **Control of Drosophila Egg Laying and Offspring Production by Refrigeration** (HADC Technical Report 54-17).

26. Simons, **Stratosphere Balloon Techniques,** pp. 5-6, 24, 36, 61-62; Dr. Berry Campbell, **Research on the Biological Effects of the Heavy Primary Cosmic Rays** (HADC Technical Report 55-8), December 1955.

27. Steinmetz, **Experimental Material,** p. 2; Simons, **Military Aspects,** p. 19; Herman B. Chase, **et al., Effects on the Skin by Cosmic Ray Heavy Particles** (HADC Technical Report 55-2, May 1955).

28. Harry F. Harlow, Allan M. Schrier, and D. G. Simons, "Exposure of Primates to Cosmic Radiation Above 90,000 Feet," **Journal of Comparative and Physiological Psychology,** Vol. 49, pp. 195-200 (April 1956); Simons and Steinmetz, "The 1954 Aeromedical Field Laboratory Balloon Flights," **Journal of Aviation Medicine,** Vol. 27, pp. 105-106, 110; Simons, **Military Aspects,** p. 18.

29. Jakob A. G. Eugster, **Effects on Living Tissue by Primary Cosmic Ray Particles** (AF Office of Scientific Research Technical Report 56-19, February 1956); interview, Maj. Simons by Dr. Bushnell, 13 December 1957; R & D Project Card (DD Form 613), Human Factors of Space Flight, 19 September 1957, p. 6; Simons, **Military Aspects,** pp. 12, 17.

30. Ltr., Maj. Simons to Col. John M. Talbot, Chief, Human Factors Division, Hq., ARDC, subj.: [Biological Results of Cosmic Ray Experiments], 6 January 1956; interview, Lt. Kuehn by Dr. Bushnell, 27 November 1957; Aeromedical Field Laboratory, "Historical Data. . . 1 July through 30 September 1957," p. 7.

31. Haymaker, "Operation Stratomouse," **Military Medicine,** Vol. 119, pp. 151-171; Steinmetz, **Experimental Material,** pp. 2-3.

32. Steinmetz, **Experimental Material,** pp. 3-4.

33. **Alamogordo Daily News,** 28 December 1954; interview, Maj. Simons by Dr. Bushnell, 6 September 1957.

34. Cf. Lt. C. H. Steinmetz, **Techniques Used for Monitoring Biological Specimens on the 1954 and 1955 Aero Medical Field Laboratory Balloon Flights** (HADC Technical Note 57-1).

35. Simons and Parks, "Improved Techniques for Exposing Animals," **Journal of Aviation Medicine,** Vol. 47, p. 320.

36. Steinmetz, **Experimental Material,** p. 6.

37. **Military Medicine,** Vol. 119, pp. 151-171.

38. Simons, **Military Aspects,** p. 22; ltr., Maj. Simons to Col. Talbot, subj.: [Biological Results of Cosmic Ray Experiments], 6 January 1956; interview, Maj. Simons by Dr. Bushnell, 13 December 1957.

39. Ltr., Maj. Simons to Col. Talbot, subj.: [Biological Results of Cosmic Ray Experiments], 6 January 1956.

40. Aeromedical Field Laboratory, "Historical Data. . . 1 October through 31 December 1957," p. 10.

41. Maj. Simons, trip report to Director of Laboratories, HADC, 14 October 1955.

42. Ltr., Lt. Col. John P. Stapp, Chief, Aeromedical Field Laboratory, to Capt. Edward G. Sperry, Hq., ARDC, subj.: [Manned Balloon Flights], 25 June 1956.

43. Cf. R. L. Schwoebel, **Strato-Lab Development, Final Report, May 1955 - November 1956** (General Mills, Inc., Minneapolis, December 1956).

44. Col. Stapp, trip report to Director of Laboratories, HADC, 29 February 1956.

45. Ltr., Col. Talbot to Cmdr., HADC, subj.: "Manned Balloon Flights Under Project 7851," 30 January 1956; Management Report (ARDC Form 111), Human Factors of Space Flight, 1 October 1955 and 24 January 1956.

46. Air Force Contract 29(600)808.

47. Ltr., Lt. Edward J. Schneider, Chief, R & D Contracting Branch, Directorate of Procurement, HADC, to Mr. J.E. Barkley, Manager, Physics and Chemistry Research, Mechanical Division, General Mills, Inc., subj.: [Capsule Design Contract], 30 November 1955; memo, Lt. Alexander P. Aven, Procurement Officer, to Maj. David G. Simons, same subject and date; Supplemental Agreements to Contract 29(600)808, especially Supplemental Agreement No. 4, 31 August 1956.

48. Management Report (ARDC Form 111), Human Factors of Space Flight, 1 October 1955.

49. Ltr., Col. Talbot to Hq., HADC, subj.: [Manned Balloon Project], 26 March 1956; interview, Maj. Simons by Dr. Bushnell, 13 December 1957; Office of Information Services, AFMDC, **Fact Sheet, Project Manhigh,** 23 September 1957, pp. 2-3. The **Fact Sheet** cited is substantially identical with one distributed to the press by Winzen Research on 14 August 1957, just prior to the final ascent.

50. Col. Stapp, trip report to Director of Laboratories, HADC, 29 February 1956; Project Development Directive, signed by Col. John R. V. Dickson, Director of Development, Dep. Cmdr./R & D, Hq., ARDC, 10 April 1956; **Fact Sheet, Project Manhigh, passim.**

51. Contract AF 29(600)808 and Supplemental Agreements, especially No. 9 (27 June 1957) and No. 13 (26 December 1957); interview, Maj. Simons by Dr. Bushnell, 13 December 1957; interview, Lt. Edward W. Kozial, Procurement Officer, AFMDC, by Dr. Bushnell, 26 February 1958.

52. Memo, Maj. Simons to Hq., 6580th Test Sq. (Special), subj.: "Balloon Flight," 16 March 1954.

53. **Fact Sheet, Project Manhigh,** pp. 8-10; interview, Capt. Parks by Dr. Bushnell, 17 December 1957; Maj. David G. Simons and Capt. Erwin R. Archibald, **Selection of a Sealed Cabin Atmosphere** (HAFB, November 1957); Otto C. Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, p. 1040 (October 1957).

54. Otto C. Winzen and Druey P. Parks, **Operation Manhigh II** (American Rocket Society, New York, 1957), pp. 3, 7, 10; motion picture films of water testing.

55. **Fact Sheet, Project Manhigh,** p. 3; **Time,** 17 June 1957. One of the more interesting items tested by "Sky Car" was a gravity meter, which the Center's Directorate of Research and Development hoped to include on the definitive manned flight as a means of obtaining improved data on the size and shape of the earth. Measurements taken from the "Sky Car" in December 1956 were overly influenced by "man-made disturbances," but showed that the procedure was feasible; unfortunately, the meter was simply on loan from Houston Technical Laboratories, and had to be returned shortly before the planned high-altitude test. (Charles S. Bagley, **Global Gravity Program** [AFMDC Technical Memorandum 57-14, October 1957], p. 2; interview, Mr. Charles S. Bagley, Geodesist, Directorate of Research and Development, AFMDC, by Dr. Bushnell, 16 December 1957.)

56. **Fact Sheet, Project Manhigh,** pp. 4, 6; ltr., Col. Stapp to Mr. Irwin Hersey, Editor, **Astronautics,** subj.: [Story on Kittinger Flight], 26 June 1957; Aeromedical Field Laboratory, "Historical Data. . . 1 April through 30 June 1957," p. 10; **Time,** 17 June 1957; interview, Maj. Simons by Dr. Bushnell, 13 December 1957.

57. **Fact Sheet, Project Manhigh,** p. 11; Aeromedical Field Laboratory, "Historical Data. . . 1 July through 30 September 1957," p. 33; Dr. Bushnell, memo to record, subj.: "On-the-spot Historical Coverage of Project Man-High," 23 August 1957; Contract AF 29(600)808, Supplemental Agreement No. 9, 27 June 1957.

58. Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, pp. 1040-1041; **Fact Sheet, Project Manhigh,** pp. 4-5.

59. Aeromedical Field Laboratory, "Historical Data. . . 1 July through 30 September 1957," pp. 31-32; **Fact Sheet, Project Manhigh,** p. 3.

60. Interview, Maj. Hubert S. Williams, Chief of Maintenance, 6580th Field Maintenance Sq., AFMDC, by Dr. Bushnell, 3 December 1957; **Fact Sheet, Project Manhigh,** p. 11.

61. **Fact Sheet, Project Manhigh,** pp. 10-12; Dr. Bushnell, memo to record, subj.: "Coverage of Project Man-High," 23 August 1957.

62. Information Services Office, AFMDC, "Information Services Summary," 10 October 1957; **Fact Sheet, Project Manhigh,** p. 12; Dr. Bushnell, memo to record, subj.: "Coverage of Project Man-High," 23 August 1957.

63. **Fact Sheet, Project Manhigh,** p. 6; Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, p. 1040.

64. Dr. Bushnell, memo to record, subj.: "Coverage of Project Man-High," 23 August 1957; Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, p. 1041.

65. Dr. Bushnell, memo to record, subj.: "Coverage of Project Man-High," 23 August 1957; **Minneapolis Star,** 20 August 1957; Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, pp. 1040-1041; Winzen and Parks, **Operation Manhigh II,** p. 19.

66. **Minneapolis Morning Tribune,** 15 and 21 August 1957; Winzen, "Bridgehead in Space," **Interavia,** Vol. XII, p. 1041; Dr. Bushnell, memo to record, subj.: "Coverage of Project Man-High," 23 August 1957.

67. **Minneapolis Morning Tribune,** 21 August 1957.

68. Transcript of Man-High capsule tape, p. 8 and **passim; Minneapolis Star,** 20 August 1957. Later Major Simons published a strikingly unusual description of the thunderheads that gathered beneath him during the night: "Although fascinatingly beautiful to watch, especially impressive for their fine detail and fantastic forms like gigantic cauliflowers or brains lighted from within, the thunderheads below posed a threat. . . ." ("Pilot Reactions During 'Manhigh II' Balloon Flight," **Journal of Aviation Medicine,** Vol. 29, p. 9, January 1958).

69. Information Services Office, Hq., ARDC, news release 24 August 1957; **Holloman Rocketeer,** 13 September 1957.

70. Aeromedical Field Laboratory, "Historical Data. . . 1 July through 30 September 1957," pp. 31-32; interview, Captain Erwin R. Archibald, Task Scientist, Environmental Control in Sealed Cabins, by Dr. Bushnell, 19 December 1957.

71. Winzen Research, Inc., **Proposal for an Airborne Laboratory of Space Physiology** (Minneapolis, April 1957).

72. Interview, Capt. Archibald by Dr. Bushnell, 19 December 1957.

III

History of Research

in

SUBGRAVITY AND ZERO-G

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

1948-1958

HISTORY OF RESEARCH IN SUBGRAVITY AND ZERO-G

1948 - 1958

Among the phenomena to be encountered in manned space flight, few, if any, have inspired as much scientific and popular speculation as that of subgravity,* including both pure weightlessness or zero-gravity and the various fractional states that lie in between zero-gravity and normal gravity conditions. In recent years, this has also been a subject of intensive research both in the United States and abroad; and the Space Biology Branch of the Aeromedical Field Laboratory, at the Air Force Missile Development Center, is one of the agencies that have made significant contributions to the research effort. This aspect of the Center's human factors program is less well known than either the rocket-sled experiments of Doctor (Colonel) John Paul Stapp or the program of high-altitude balloon flights culminating in the record Man-High (II) ascent of 19-20 August 1957. Yet the current program of subgravity research has roots at Holloman Air Force Base that go back before the rocket track was even built, and before the first balloon with biological payload was launched.

Subgravity research as a clearly defined field of study had its real beginning just after World War II. It has its primary application in the field of ultimate space flight, where gravitational attraction will still be present but will be normally counterbalanced by other factors, rather than in conventional aviation. Nevertheless, brief exposures to subgravity can and do occur in aircraft flight, so that the problem attracted some slight attention even earlier from specialists in aviation medicine. Moreover, even before World War II, a limited amount of subgravity experimentation had already taken place.

A German aeromedical scientist, Doctor Hubertus Strughold--now at the School of Aviation Medicine, Randolph Field, Texas--staged a particularly memorable experiment to study human orientation when deprived of gravitational cues from the external pressure sense. This is only one of the sense mechanisms that supply information on bodily weight and direction, but it is important in flying, where it is activated by the pressure of the aircraft seat on a flier's skin and thus provides the familiar "seat-of-the-pants sensation." In order to simulate a weightless condition as far as this one sense is concerned, Strughold anesthetized his buttocks with novocaine. He then flew a series of acrobatic maneuvers, and in his peculiar condition he found the experience very disagreeable.[1] Another German investigator, Heinz von Diringshofen, whose main work concerned human tolerance to multiple g-loads, began exposing test subjects in 1938 to a few seconds of subgravity simply by putting an aircraft through a vertical dive.[2]

The early experiments of Von Diringshofen and Strughold did not lead to any concerted or continuing program of subgravity research in Germany. In the immediate post-war years, German scientists contributed some valuable theoretical studies relating to subgravity, as did scientists in other European countries. The first major landmark in actual subgravity experimentation, however, was a series of high-altitude rocket flights with animal subjects started in 1948 by the United States Air Force.[3] The agency immediately in charge was the Aero Medical Laboratory at Wright Field, which then formed part of the Air Materiel Command and which is now a unit of Wright Air Development Center. The vehicle used at first was the German V-2 rocket, of which large numbers had been captured and brought to White Sands Proving Ground in south-central New Mexico to be used in high-altitude research. No less than five V-2 animal flights were launched from White Sands, and in each case the project obtained a wide variety of support services from Holloman Air Force Base, on the opposite side of the same Tularosa Basin. For all flights except the very first, actual preparation of the nose cone including the animal capsule took place in Holloman laboratory facilities. And when, in 1951, the Aero Medical Laboratory began using the newly-developed Aerobee research rocket for its experiments, launch operations as well were transferred entirely to Holloman.

The Aero Medical Laboratory's animal rocket flights were not designed pure-

* The term "subgravity" will normally be used in this study to denote all states in which the gravitational force is less than the normal one "g." "Weightlessness" is commonly used in the very same broad sense, but can be confusing. The word literally suggests a complete absence of weight, or zero-gravity, whereas the writer often is referring in fact to a small fractional gravity state--"virtual" weightlessness as it is sometimes expressed.

ly for subgravity studies. Their purpose was to expose living subjects to as many as possible of the potential hazards of space flight. In practice, however, a rocket trajectory was too brief to obtain significant exposure to such hazards as primary cosmic radiation, while fairly moderate g-forces were involved both in rocket acceleration and in the opening shock of the parachute recovery system that was designed to carry the capsule safely back to earth. The far-reaching significance of these flights lies rather in the exposure of animals to subgravity lasting for as much as two or three minutes, during the period of coasting and free fall from rocket burnout to the point where the descending capsule again met appreciable atmospheric drag. At that time, no other experimental method could come close to providing as long an exposure. Moreover, for subgravity research, unlike cosmic radiation studies, two or three minutes was not too short a period for some disturbing symptoms to make themselves felt, if in fact any were likely to occur.

The hero of the first animal rocket flight was a nine-pound rhesus monkey named Albert. He was brought to New Mexico by a team from the Aero Medical Laboratory at Wright Field that included Doctor (Captain and later Lieutenant Colonel) David G. Simons, who now heads the Aeromedical Field Laboratory at Holloman. Albert was carefully instrumented to record both heart and respiratory action. On 18 June 1948 he was finally launched toward space. Unfortunately, his brief trip in a V-2 to an altitude of thirty-seven miles was plagued with a series of operational failures, and no data were obtained. Neither did Albert manage to get back alive: the parachute system failed.

A year later the Wright Field scientists, including Doctor Simons, tried again. On 14 June 1949, Albert (II) reached an altitude of about eighty-three miles. There was still no live recovery, since the parachute system failed again. However, data were successfully recorded throughout the flight and indicated that the second Albert suffered no serious ill effects from weightlessness, cosmic radiation, or any other hazard of space flight.

After two more monkey flights, of which one was marred by unsatisfactory rocket performance and the other essentially repeated the outcome of the Albert (II) flight, a mouse was chosen as passenger in the fifth and last of the space biology V-2's. The mouse was not instrumented for heart action or breathing since this time the primary objective was to record the conscious reactions of an animal under changing gravity conditions. For this purpose, the animal capsule was equipped with a camera system to photograph the mouse at fixed intervals. As usual, the recovery system failed--the mouse did not survive impact. But photographic evidence showed that the mouse retained "normal muscular coordination" throughout the subgravity phase, even though "he no longer had a preference for any particular direction and was as much at ease when inverted as when upright relative to the control starting position."[4]

With the first aeromedical Aerobee firing, on 18 April 1951 from Holloman Air Force Base, project scientists reverted to the pattern of the V-2 monkey flights. The result was quite familiar: physiological data on a monkey's breathing and heart rates were successfully recorded, there was no sign of any gross disturbance in the subject, and the parachute failed again. Finally, with the second Aerobee animal flight of 20 September 1951, the long-awaited breakthrough in parachute recovery was successfully accomplished. An instrumented monkey was safely brought back from peak altitude of 236,000 feet, and so was a grand total of eleven mice that had gone along with him. Successful recovery was again accomplished on the third and last Aerobee flight of the series, which took place on 21 May 1952. All passengers--two monkeys and two mice --returned safely to earth, and one of the monkeys is still alive and healthy in a Washington, D. C., zoo.

Nine of the second Aerobee's mouse contingent served primarily as cosmic radiation subjects, but all other mice, like the mouse on the last V-2, were studied photographically for their reactions during the subgravity state. One of these had undergone a prior operation removing the vestibular apparatus of the inner ear that is responsive to gravitational forces and helps give both mice and human beings a sense of equilibrium. The mouse was already accustomed to orient himself by vision and touch exclusively and did not seem troubled by loss of gravity during the flight. One of the three normal mice used as subgravity test subjects was also free from any sign of disorientation during exposure to subgravity, apparently because it had a paddle to cling to and retained full possession of tactile as well as visual references. But the two remaining mice did show some signs of disorientation.

Since May 1952, there have been no

more rocket experiments with animal subjects either at Holloman Air Force Base or elsewhere in the United States. For a few years, at least, experiments of this type have become a monopoly of the Union of Soviet Socialist Republics, where the first animal-carrying rocket is said to have been launched in 1951. The Russians preferred dogs as test subjects, and refrained from giving them anesthesia before takeoff. They have also claimed that no dog was ever lost through failure of his breathing equipment or "effect of external factors," but they have not specified how many may have been lost for other reasons.[5] If United States experience is any guide, one is tempted to assume that the Russians must regard parachute failure as an "internal" factor! Be that as it may, the Russian methods and test results generally resembled those of the earlier Air Force animal rocket flights--until, of course, they used a rocket to place a dog in orbit in November 1957.

From the standpoint of subgravity studies, the unique quality of this last achievement was the length of the exposure obtained, from the final rocket burnout until the death of Laika, the satellite dog, roughly a week after launching. Technically speaking, a minor limitation of this experiment was the presence of fractional g-forces caused by the tumbling of the satellite vehicle. A more obvious limitation for subgravity studies or any other research objective was failure to bring back either the dog itself or a photographic record for later study and observation.[6]

According to results published so far concerning the Russians' satellite experiment, the effects of rocket acceleration on Laika's heart beat, though tolerable, persisted much longer after acceleration ceased than would have been the case if recovery from the same high g-load had been made in a normal one-g field. Russian scientists attributed this result directly to the influence of a post-acceleration subgravity state. However, there was still no sign of disabling ill effects on the test subject as a result of subgravity exposure. The dog's eyesight allegedly "compensated to a certain degree the disturbance of locomotive power" that was due to subgravity, although under the conditions of the test it is hard to see how this could be anything more than a reasonable hypothesis.[7]

Even before the United States abandoned the field of animal rocket experiments to the Russians, at least for the present, scientists at different Air Force installations had branched out into still another fruitful type of subgravity research, using the airplane as test vehicle. In May 1950, two former German scientists working at the School of Aviation Medicine, Doctors Fritz and Heinz Haber, delivered a paper in which they explained how to achieve over thirty seconds of subgravity in aircraft flight. The method was to fly the plane in a parabolic arc or "Keplerian" trajectory in which centrifugal force would exactly offset the downward pull of gravity and engine thrust would counterbalance air friction. This was not an easy thing to do, and even with an expert pilot at the controls one could expect absolute weightlessness for only part of the total subgravity trajectory. Nevertheless, the Habers' proposal offered the first method for obtaining a really significant subgravity exposure in manned flight.[8]

During 1951, the new procedure was tested at Edwards Air Force Base in California and at Wright Field in Ohio. At Edwards, the noted test pilot Scott Crossfield and the Air Force's Major Charles E. Yeager both flew a number of Keplerian trajectories, the former working on behalf of the National Advisory Committee for Aeronautics. At Wright Field, similar experiments were conducted by Dr. E.R. Ballinger. Apparently none of these early experiments achieved more than a few seconds, at most, of true zero-gravity, but total subgravity trajectories were in reasonably close accord with the Habers' predictions. Test results showed a tendency for subjects to overreach with their arms during subgravity. Symptoms of disorientation also appeared in some cases, but, on the whole, these flights indicated no major difficulties in orientation as long as the subjects were firmly belted in and had full visual references.[9]

This sudden burst of subgravity flights in the United States was followed by a period of relative inactivity during 1952-1954. Meanwhile, related experiments were being conducted during these same years in Argentina by the Austrian-born scientist Dr. Harald J. A. von Beckh, who had left Germany for South America shortly after the war. Von Beckh introduced still another animal to the menagerie of subgravity test subjects, the South American water turtle. He had one turtle whose vestibular function had been injured accidentally; and he found that this turtle showed much better coordination and orientation during an aircraft subgravity flight than his normal companions. Like the mouse that had a special vestibular

operation before going up in the second aeromedical Aerobee, the turtle had apparently learned to compensate visually for the lack of normal gravitational cues. Even the normal turtles, however, gradually improved their performance after a sufficient number of flights.[10]

In his turtle experiments, Von Beckh achieved subgravity exposures up to seven seconds by means of vertical dives. Subsequently he, too, adopted the parabolic flight pattern and shifted from turtles to human subjects. The latter submitted to a series of eye-hand coordination tests, in which they showed the familiar tendency to overreach during subgravity but resembled Von Beckh's turtles in their capacity to improve with later flights. Von Beckh was also much interested to observe that when the plane entered its subgravity arc by a maneuver causing high acceleration forces, the recovery from acceleration-induced blackout took appreciably longer than usual.[11] In a sense this foreshadowed the experience of the Russian satellite dog, and suggested a special topic for further experimentation. However, Von Beckh cut short his stay in Argentina to take a position in the United States with the Human Factors Division of the Martin Company. Later still, in January 1958, he joined the staff of the Air Force Missile Development Center's Aeromedical Field Laboratory. There he assumed direction of the present subgravity program, which had been started--perhaps it would be better to say reactivated--in 1954.

Later Subgravity Studies at Holloman, 1954 - 1958

The sum total of subgravity research accomplished prior to 1954 still was not great, but it allowed certain tentative conclusions to be drawn. There seemed to be no major respiratory or circulatory hazards resulting from weightlessness, although Doctor David G. Simons carefully pointed out that respiratory and circulatory complications might arise as a secondary effect of "emotional and autonomic reactions which are essentially the same whether caused by weightlessness, a rough sea, or an obnoxious mother-in-law." Simons generalized further, on the basis of studies up to and including Von Beckh's, that subgravity should normally produce "minimal discoordination and no disorientation. . .as long as the subject retains tactile and visual references."[12]

What was needed now was a much greater accumulation of detailed test data to verify or revise preliminary conclusions and to reveal still other possible effects of subgravity. Better test instrumentation was also needed, especially to record all the variations of gravity force from true zero-gravity up to a normal one-g state. This would be of great help to any pilot attempting to fly a subgravity trajectory. In addition, most suggestions for future space stations have provided for some form of rotation in order to avoid absolute weightlessness, through the artificial creation of a centrifugal force, but nobody knew exactly how many hundredths of a g must be generated to produce what results. It might also turn out that no rotation at all is needed; but in any case there was an urgent requirement for research data on this and other ramifications of the subgravity question.[13]

By the same token, there was ample reason to establish a formal subgravity program at Holloman within the framework of the Space Biology Branch of the Aeromedical Field Laboratory. Unlike the earlier V-2 and Aerobee flights, the present program is part of the Center's own project workload. The Aeromedical Field Laboratory had been founded in 1951 as a field station for project scientists operating from the Aero Medical Laboratory at Wright Field, but in January 1953 it became a function of the local Center (then known as Holloman Air Development Center), and in October 1953 subgravity studies were specifically included in the Holloman laboratory's mission. In the following year, 1954, work on subgravity actually got underway as Task 78501 of the newly-created Project 7851, Human Factors of Space Flight. Doctor (at that time Major) David G. Simons was project officer of Project 7851, as well as head of the laboratory's Space Biology Branch. Technical Sergeant John T. Conniff was the original task scientist for Task 78501, Subgravity Studies.[14]

For some time, with funds and manpower both limited, the main task activity consisted of planning and preparations for an ultimate test program. Sergeant Conniff's subgravity duties were not so engrossing as to prevent him from continuing as head of the laboratory's Electronics Unit;[15] indeed the latter position was presumably of advantage to him in collecting instrumentation for the subgravity program. Nevertheless, a preliminary aircraft flight took place at least as early as September 1954, using a T-33, to evaluate some of the problems involved in flying

a parabolic subgravity trajectory. More flights were made early the following year with an F-89, again mostly for evaluating techniques and instrumentation.[16]

The program was not really intensified until after the assignment of Captain Grover J. D. Schock as task scientist on 1 July 1955. Captain Schock--whose contributions to subgravity research later qualified him as the first known scientist to receive a Doctor of Philosophy degree in space physiology--initiated subgravity flights in an F-94C aircraft in the fall of 1955, using himself as one of the various test subjects. The F-94C became the standard test vehicle for subgravity research, and Task 78501 remained the primary duty of Captain Schock until the beginning of 1958, when Von Beckh took over as task scientist. Captain Schock then branched out into other lines of activity for the Aeromedical Field Laboratory, but without abandoning his previous interest and participation in the subgravity program. Moreover, he kept one special foothold as task scientist for Task 78530, Psychophysiology of Weightlessness. This was a task of the recently-established Project 7857, Research in Space Bio-Sciences. It is not concerned with the aircraft subgravity flights at Holloman, but with certain research to be done by outside investigators on a contract basis as well as a limited amount of "in-house" effort.[17]

The F-94C flights, which have been the primary activity of Task 78501, are capable of giving subgravity trajectories of more than thirty seconds in duration; and more than one such trajectory or "run" can be scheduled on a single flight. The amount of actual zero-gravity is always considerably less, although the exposures have increased steadily. Early in 1958, the maximum zero-gravity obtainable in a test trajectory was about twenty-two seconds, and even this exposure was not continuous but was interrupted by momentary lapses into some minute fraction of positive or negative g-force. Nevertheless, the period was long enough for many types of experimentation, and it compared favorably indeed with the two or three seconds of true weightlessness achieved on some of the very earliest parabolic test flights.[18]

This advance is of course due to improvements both in flight techniques and in test instrumentation. One item of instrumentation still in use when Captain Schock joined the program was a golf ball dangling on a string from the aircraft canopy--a gadget that accurately showed when pure weightlessness had been achieved but could not measure degrees of subgravity. The standard aircraft g-meter was not very satisfactory, either, for instrumenting subgravity flights. However, Captain Schock devoted a major part of his attention to the instrumentation problem. More precise methods have since been devised, using a combination of differently-placed accelerometers. Information on the exact g-forces being experienced is constantly relayed to the aircraft pilot by two sensitive microammeters installed in his field of vision, and the same information is carefully synchronized with a film record of the test subject's reactions.[19]

Unfortunately, the subgravity program was also afflicted with more than its share of aircraft trouble. Apart from normal maintenance problems, the F-94C aircraft used in the program developed such special troubles during subgravity flights as loss of oil pressure, loss of hydraulic fluid, and "sticking" of the trim tab motor. These difficulties, as well as the presence of extra equipment mounted inside the aircraft, caused a good bit of worry to flying safety and maintenance officers, and required suspension of tests on several occasions. But in the end all the difficulties were shown to be of little importance or else were corrected. Both Lockheed, the aircraft manufacturer, and Pratt-Whitney, the engine manufacturer, were extremely helpful in finding solutions. Moreover, the difficulties over hydraulic fluid and oil pressure suggested some profitable investigations on the behavior of fluids under subgravity conditions, shaking them or forcing them from a squeeze bottle in subgravity flight.[20]

Still another problem that arose was that standard microphones in the F-94 (and earlier in the F-89) were unable to transmit clear messages between pilot and test subject during subgravity. This led to research on the problem and installation of a more satisfactory type of microphone. As a result, Captain Schock is now able to conclude, "Voice communications in future space vehicles should present no problem."[21]

It is worth noting that so many materiel problems of subgravity flight were discovered in the course of human factors research. Nevertheless, the main interest of the subgravity program does not lie in the effects of subgravity on aircraft parts and equipment but in the reactions of human test subjects. And it is well to note, first of all, that not all human subjects reacted the same way. Some have positive-

ly enjoyed the gravity-free state, while others have on occasion felt extreme motion sickness with nausea and vomiting. Among the former can be included Sergeant Conniff, the original task scientist, and Captain Druey P. Parks, who has participated in this as in all other programs of the Space Biology Branch. Among those who have suffered varying amounts of discomfort, Captain Schock definitely includes himself. It is perhaps significant that one who professes no distaste for subgravity is Captain Joseph W. Kittinger, Jr., better known as the test pilot for the Man-High (I) balloon flight, who piloted a great many subgravity trajectories at Holloman before his recent transfer to Wright Air Development Center. In his case, it is likely that a broad previous flying career helped prepare him for the experience, although no number of flying hours is any guarantee in itself against feeling ill at ease during a subgravity exposure.[22]

The apparent existence of wide variations in human tolerance suggests that one criterion for selection of crews in space travel may well be a comparison of monitored responses during experimental subgravity exposures. However, still more information is needed on these varying personal sensations. The sickness felt by some may be related to the rapidly changing g-forces encountered in a complete test flight, including the high acceleration and deceleration that sometimes mark the plane's entry to and exit from the subgravity parabola. In that case, the same symptoms might not be associated with long-duration, continuous subgravity exposures. On the other hand, those who easily endure thirty seconds of subgravity might conceivably do less well with a three-minute--or three-month--dose of the same thing. Laika's experience is encouraging in this respect, but hardly conclusive.

The Holloman subgravity flights have also featured a variety of sensomotor performance tests. These indicate that subgravity need not seriously impair a subject's ability to touch his nose with his finger tip, mark x's in a row of squares, or perform other similar operations--provided always that he retains a visual frame of reference, and provided also, of course, that he has not first become violently ill with motion sickness. This conclusion closely parallels those tentatively drawn from the earlier test programs of Ballinger, Von Beckh and others. Neither does eating peanut brittle offer major problems during weightless trajectory, as long as the food is first well masticated and then forced to the back of the mouth where the swallowing reflex goes into action without regard to gravity. Drinking seems to require use of a squeeze bottle, cups and glasses being quite useless during weightlessness. Water must be forced to the back of the mouth by the tongue, but again the swallowing reflex is unimpaired.[23]

A somewhat different variety of experiment has demonstrated that human subjects, deprived of normal visual references, will perceive oculogravic illusions such as "apparent linear motion of a fixed 'target' during a ballistic [Keplerian] trajectory." For these tests both the subject's head and the "target"--a small luminous cross--were placed under a large and ominous-looking black hood. The illusion was always most pronounced during the periods of increased g-forces on entering and leaving the subgravity parabola. The target appeared to stabilize--though at a higher than normal position--during the weightless phase itself, except for certain oscillations that were attributed to the failure of the test aircraft to maintain an even weightless trajectory.[24]

When Doctor von Beckh joined the Holloman program, he brought with him as a carryover from his work in Argentina a special interest in the effects of subgravity on ease of recovery from acceleration-induced blackout or greyout. At Holloman, he has initiated flights designed to produce subgravity either just after or just before exposure to a force of roughly four g's, with a peak of five or six. This procedure duplicates the type of conditions to be met in takeoff and re-entry of manned space vehicles. The test services has only recently started, but when further advanced it should yield important research data.[25]

Nor have animal subjects been forgotten in the Holloman test flights. The current pet of subgravity research--at least in the Free World--is the familiar cat, which is of interest for its highly developed vestibular function. It is actually more reliant on this function for balance and orientation than are human beings. The cat is also noted for its reflex ability to land squarely on all fours even after being dropped upside down, and tests were conducted to determine how this righting reflex operates during subgravity. Judging by the test results, it does not work very well. In order to examine the matter more closely, Captain Schock obtained certain cats that had undergone operations removing the vestibular apparatus wholly or partially. When these cats were tested in the same manner, it appeared that animals still

having even partial vestibular function were confused. On the other hand, animals wholly deprived of this function and accustomed to do without it remained fully oriented and in possession of normal reflex responses unless their eyes were covered. This last observation confirmed once again the critical importance of visual orientation.[26]

Although the test program has centered primarily around subgravity trajectories flown in jet aircraft, other tests have been performed in simulated subgravity conditions at ground level. Some of the reactions of a human subject immersed in water are similar to those encountered in a subgravity state; for instance, external pressure on the skin is so evenly distributed around the body surface, when under water, that this pressure is perceptible barely if at all, just as in a weightless condition. Accordingly, in the spring of 1957, Captain Schock staged a series of experiments at the indoor pool of the El Paso Young Men's Christian Association, with the subject on a rotating seat in eight feet of water and blindfolded. Later in the same year, underwater experiments were conducted in the pool of the New Mexico School for the Visually Handicapped in Alamogordo. Such tests have demonstrated an impairment of orientation somewhat like that experienced in aircraft experiments where the subject lacks normal visual cues. In one type of underwater experiment, subjects were tilted as much as twenty-two degrees before perceiving the tilt. The underwater tests have also made a definite contribution to the methodology of subgravity research, and offer the advantage of more prolonged exposure to test conditions than a comparable aircraft trajectory.[27]

The Aeromedical Field Laboratory has worked in close cooperation not merely with the owners of indoor pools but also with Air Force and private researchers interested in subgravity studies. The School of Aviation Medicine, in particular, has been conducting an active subgravity program at Randolph Air Force Base, Texas. Under the principal direction of Dr. Siegfried J. Gerathewohl, this program in its present form dates from 1955; it, too, has been centered around subgravity test parabolas flown in jet aircraft. The general categories of testing and research have been much the same as in the Holloman program, but in some respects work at Randolph has pointed the way, while in other respects--notably instrumentation --the Holloman program has been generally more advanced. Fortunately, there has been little if any sign of the rivalry that has sometimes marred relationships between research programs of the Aeromedical Field Laboratory and related efforts of the Aero Medical Laboratory at Wright Field. There has in fact been a mutually profitable exchange of data and ideas, and though a spokesman for the School of Aviation Medicine has admitted that some overlapping research effort exists in subgravity studies, he went on to explain that this was actually "necessary because of the importance of the role that subgravity states will play in the immediate future."[28]

In addition to the current subgravity flights at Holloman and Randolph Field, there is at least one more active program of a similar nature now going on. It is in Soviet Russia, and though the Russians do not seem to have publicized aircraft subgravity flights to the same extent as their animal rocket experiments, they claim to have exposed human subjects to about the same period of weightlessness--forty seconds--that has been achieved by similar research in the United States.[29]

There has been no direct exchange of information between Holloman and Soviet researchers in this field. However, the cooperation of various outside institutions in the United States has been enlisted for the Holloman subgravity program on a contract basis. Researchers at the University of Illinois assisted Captain Schock's study of the vestibular mechanism in cats, performing the special vestibular operations on cats used in Holloman subgravity flights. They have also been working on techniques for attaching a recording device directly to the vestibular portion of the eighth cranial nerve. The Yellow Springs Instrument Company developed an airborne galvanic skin resistance meter, to permit continuous recording of resistance to electric impulses under stress in subgravity experiments. This instrument is at present being fitted at Holloman with the necessary in-flight recording apparatus. Cornell Aeronautical Laboratories, finally, made a theoretical study under contract of animal experiments that might be performed both in test vehicles now available for subgravity research and in more advanced vehicles that may become available for such studies later on. Additional contracts related to subgravity research have recently been initiated; the efforts mentioned, however, antedate the launching of even the first Russian satellite, and have been substantially or wholly completed.[30]

The same Russian satellite hastened the end of an Air Force-wide austerity

drive that was unleashed in the first quarter of fiscal year 1958 and which unfortunately had administered a temporary setback to the Holloman subgravity program. The Air Force Missile Development Center was ordered to slash expenditures, and research projects generally had to suffer more than missile development. Subgravity studies suffered more than most: a directive issued on 27 August 1957 ordered "cessation of work" effective immediately. The "cessation" was soon clarified to refer only to work that cost money, such as the F-94C flights, which were calculated to use up sixty-three dollars an hour in operating expense without counting maintenance and overhead. Captain Schock in his official role as task scientist could still go swimming, and could plan and theorize to his heart's content. His specially-treated cats arrived from the University of Illinois right in the middle of the austerity drive, but he was able to toss them up and down in the laboratory, taking observations on how they fell; these observations could be compared later with the results of inflight experiments, as soon as an aircraft was again made available.[31]

Subgravity contracts outstanding were scaled down slightly at the same time, but this occurred under a command-wide order for five percent reduction in expenditure on effort-type contracts. All Center research programs were similarly affected, and the impact on subgravity studies was barely noticeable compared with the suspension of F-94C flights. Moreover, on 1 October 1957 austerity was relaxed by Center decision to the point of authorizing a small number of test flights, for the specific purpose of having the cats flown at last. Later still, with the appearance of the Russian satellites, austerity was abandoned altogether. By the start of 1958, the subgravity program was back in full swing, although time lost could never be wholly regained.[32]

The Present Outlook for Experimentation in Subgravity Conditions

In the spring of 1958, Captain Schock put forward a "philosophy of weightlessness research" in the following terms:[33]

> To date investigations of the biological effects of weightlessness have been confined almost entirely to observations on the effects of weightlessness on orientation and coordination of animal and human subjects. There is a definite need for this type of research. However, only short periods of weightlessness have been obtained in jet flights and rocket flights. The use of Ballistic Missiles and Bio-Satellites affords a chance for experimentation into the effects of prolonged weightlessness.
>
> Using these methods, biological research should be channelled away from an observation experimentation to a [more strictly] experimental approach. Specifically, investigations should be undertaken into recording the effects of weightlessness on the utricular mechanism, possible loss of reflexes, and greatly enlarged recordings of physiological data when these parameters are controlled by the autonomic nervous systems. The effects of prolonged sensory deprivation--and true weightlessness can be considered a sensory-starved environment--must be energetically investigated. The use of water or other appropriately diluted solutions affords an excellent method of investigating the effects of sensory deprivation.
>
> The psychology of exposure to weightlessness has been little investigated. Past research has attempted to record incidences of "motion sickness" without really tying down the etiology. Perhaps this is autonomically controlled, but perhaps it is psychologically induced.
>
> The effects of pre-weightlessness accelerations and post-weightlessness accelerations have been little considered in the past. The profile of a Bio-Satellite launching reveals that immediately after burnout any biological system in the nose cone is subjected to weightlessness immediately after a rather large acceleration. What the consequences of this may be is unknown. Conversely during re-entry the effects of high accelerations subsequent to prolonged exposure to weightlessness are purely conjectural. Simulating these conditions is dif-

ficult using either the centrifuge or deceleration tracks. It is in these problem areas that future zero gravity research must be directed.

Subgravity studies at the Aeromedical Field Laboratory are at present attempting to meet many of the objectives stated by Captain Schock. As indicated above, pre- and post-weightlessness accelerations are the subject of a series of test flights being conducted by Doctor von Beckh. Similarly, in order to continue study of "the effects of sensory deprivation" on a body under water, the laboratory is preparing a small tank or pool of its own. This facility will measure just twelve feet wide by twelve feet deep and will be equipped for heating; thus the water can be maintained at skin temperature, the better to produce "a sensory-starved environment."[34]

But there is also a definite need for more advanced test vehicles. The F-94C still has not outlived its usefulness; nevertheless, substantially longer intervals of subgravity could be achieved either in century-series fighters or in certain types of missiles. One obvious step would be to progress from the F-94 to the F-100, which has been the standard chase aircraft on the Holloman range since 1956. In fact plans already exist to use this aircraft type in the subgravity program. But the two-seat F-100F, which would be required for the test flights, is in rather short supply. The first one reached Holloman only in the fall of 1957, with photographic chase as its primary mission, and because of modifications needed for subgravity work, none has been made available as yet for subgravity studies.[35]

For animal experiments, the Aerobee is again a possibility, offering up to three and a half minutes of subgravity, although a later model would be involved than the one used previously for biological research at Holloman. Better still would be a long-range ballistic missile, but the "ultimate" test vehicle for subgravity research with either animal or human subjects is the biological satellite. Only the satellite can provide a test environment that is truly "space-equivalent" in duration of exposure as well as in the mere presence of weightlessness.[36]

Naturally, any test program involving intermediate or intercontinental ballistic missiles or satellite vehicles must involve more than one research organization. In any program of this sort, however, the Aeromedical Field Laboratory can be expected to take part. There is currently an "in-house" effort under Captain Schock directed toward the use of ballistic missiles in aeromedical research. Similarly, the laboratory's present chief, Doctor (Lieutenant Colonel) David G. Simons, is head of the interservice Biosatellite Coordination Committee. Several other members of the laboratory staff, including Captain Schock, belong to the same committee, and Captain Schock is currently devoting much of his time to this work. Among other things, he is initiating a series of research contracts between the Air Force Missile Development Center and outside scientists in support of the biosatellite program. One such contract, for example, will be designed to provide a satellite experiment on possible degeneration of muscle tone in animals as a result of prolonged exposure to weightlessness.[37]

There are, of course, more reasons than a background in subgravity studies for the prominent role of the Aeromedical Field Laboratory in biosatellite planning. The Holloman laboratory has also been engaged in active research (as in Project Man-High) on sealed cabin environment and on recovery of biological capsules. In all these fields, it has much to contribute toward a successful biosatellite program and toward man's ultimate conquest of space. Its contributions, moreover, will be the fitting culmination of a record of achievement that really began when Holloman Air Force Base provided essential support to the very first United States experiments in weightlessness and space biology.

NOTES

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3. A more detailed account of these flights, as well as the sources of information used, will be found in **The Beginnings of Research in Space Biology at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946-1952** (AFMDC Historical Division, January 1958).
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13. Cf. Management Report (ARDC Form 111), Human Factors of Space Flight, 24 January 1956.
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15. For an example of his other work, see Lt. Druey P. Parks, T/Sgt. John T. Conniff, and A/2c John A. Goldsmith, **Ground-to-Air Operation of Aero Medical Field Laboratory VHF Handi-Talkie** (HADC Technical Note 55-1).
16. Project 7851, "Monthly Historical Report," 8 October 1954, and **Weekly Test Status Report,** 22 February, 1 and 8 March 1955.
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22. Interview, Capt. Schock by Dr. Bushnell, 5 December 1957; interview, Capt. Joseph W. Kittinger, Jr., Flight Test Division, AFMDC, by Dr. Bushnell, 12 December 1957; R & D Project Card, Human Factors of Space Flight, 19 September 1957, p. 7; Management Report, Task 78501, 28 October 1957.
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26. Management Report, Task 78501, 28 October 1957; Aeromedical Field Laboratory, "Historical Data. . .1 October through 31 December 1957," p. 11.

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IV

Major Achievements in

BIODYNAMICS: ESCAPE PHYSIOLOGY

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

1953 - 1958

COLONEL JOHN PAUL STAPP

MAJOR ACHIEVEMENTS IN BIODYNAMICS: ESCAPE PHYSIOLOGY

1953 - 1958

During recent years the Air Force Missile Development Center has made important contributions to the Air Force human factors program in two broad fields: space biology and biodynamics. Under the heading of space biology, it has been engaged in research on biological effects of cosmic radiation, on sealed cabin environment, and on subgravity, all of which have been discussed in previous historical monographs.[1] Under the heading of biodynamics--which can be defined as the study of the effects of mechanical forces on living tissues--its research efforts cover a variety of problems ranging from the merits of automotive seat belts to patterns of deceleration in space flight. At first glance, some of these problems of biodynamics have little in common. In each case, however, the research program is centered around a unique Holloman complex of test facilities, of which the 35,000-foot high-speed test track is only the best known example. Moreover, each of the various research tasks in biodynamics is in some measure an outgrowth of the deceleration and windblast studies which began at Holloman Air Force Base in 1953 under the direction of Doctor (Lieutenant Colonel and later Colonel) John Paul Stapp, and which were related primarily (though not exclusively) to the problem of escape from high-performance aircraft.

The research project that Colonel Stapp personally brought to Holloman when he came to assume command of the Center's Aeromedical Field Laboratory in April 1953--Biophysics of Abrupt Deceleration--was specifically oriented toward the study of high-speed escape from aircraft. The escape problem remained one of the most important research topics of Project 7850, Biodynamics of Human Factors in Aviation, that was drawn up in 1954 to supplement and in large measure to supersede the former project. Research on this same theme has been reoriented but by no means eliminated since March 1958, when Project 7850 was rewritten as Biodynamics of Space Flight. And it was a series of experiments directly related to escape physiology, Colonel Stapp's own rocket-sled rides on the Holloman track, that first brought nationwide attention to the Holloman aeromedical organization.

The high-speed escape problem was one of imposing magnitude. A pilot bailing out at transonic or supersonic speed had to face first the ejection force required to get him out of his plane, then the sudden onslaught of windblast and wind-drag deceleration, likely to be followed by dangerous tumbling and spinning. Any one of these forces taken separately was a potential cause of injury or death, not to mention the anxiety on the part of aircraft pilots who did not know if they would survive or not in case of ejection. For, at the time research on this problem at Holloman began, the escape systems available were either admittedly inadequate or of unproven worth for aircraft having performance capabilities above mach one in speed and 45,000 feet in altitude.[2] Since aircraft with this range of performance were already in existence, and were destined to assume ever greater importance in the Air Force inventory, there was a glaring need for reliable data on human tolerance to all the forces that could be encountered in escape at the indicated speeds and elevations. The fact that such information was not already available was another case of the lag, often deplored by aeromedical scientists, between aircraft design and human factors research.[3]

Test Directive 5200-H1 for Biophysics of Abrupt Deceleration, dated 15 April 1953, proposed to remedy this situation at least in part, setting forth as its objective:

> A program of experiments with the High Performance Linear Decelerator to study tolerance and survival limits for (1) Linear Deceleration, (2) Windblast in a Linear Deceleration Field, (3) Tumbling in a Linear Deceleration Field, and (4) Linear Deceleration with Tumbling and Windblast, as factors of the problem of escape from high speed, high altitude aircraft. . . .Recommended limiting values established by these experiments will determine the design of escape devices and the choice of ejection seats or of ejection capsules for a particular aircraft.

This test directive, with later amendments, was the official basis for Colonel Stapp's research at Holloman until Project 7850 became fully operative early in 1955. It stated further that the "current military need" was to study tolerance to deceleration up to fifty-five g's, but this fig-

ure was subsequently revised,[4] and all such figures were naturally for rough guidance only. In any case, the maximum number of g's was only one of the factors involved in this study. Not only were tumbling and windblast to be explored, as stated in the directive, but also the rate of onset and duration of g-forces would be considered as affecting the total deceleration that a human body can withstand. The research assignment was thus arduous and complex, but, as Colonel Stapp once stated in a slightly different connection,

> . . . .one factor is encouraging. There are only two models [male and female] of the human body currently available, with no immediate prospects of a new design; any findings in this research should provide permanent standards.[5]

In his own previous experiments on the 2,000-foot deceleration track at Edwards Air Force Base, California, Colonel Stapp had already experienced forces up to roughly 46 g's at 500 g's per second rate of onset. Both this experiment and one in which a co-worker withstood over 38 g's at 1370 g's per second produced definite signs of shock but no permanent ill effects. Colonel Stapp also directed chimpanzee tests while at Edwards, exposing the animal subjects to plateaus of 65 g's, rates of onset of approximately 3400 g's per second, and peaks of about 150 g's, without finding the lethal point or even the point of irreversible injury. However, the duration of decelerative forces was always very short. Durations ranged from .15 to .42 second in the human experiments, which attained a top speed of only 226 feet per second; and there were no experiments on deceleration combined with windblast and tumbling.[6]

Thus the Edwards tests did not adequately answer the questions posed in the project Biophysics of Abrupt Deceleration. They clearly suggested that the human body, if properly positioned and secured, could endure any aircraft crash forces in which the aircraft itself survived,[7] but they did not duplicate the conditions of high-speed escape. For the latter purpose, the Holloman high-speed track, originally built in 1949 as a rail launcher for the Snark missile, was especially well suited. It was 3550 feet long (before the first of a series of track extensions) and was fully instrumented. It also had a water braking system as compared with the mechanical friction brakes used on the 2000-foot Edwards deceleration track. The water brakes permitted both high deceleration forces and a wide range of duration and rate of onset.[8]

Deceleration and Windblast Experiments on the Holloman Track

The Holloman track had previously been used for captive testing of missiles and their components, but until Colonel Stapp's arrival had never been used in biophysical research. To be sure, Colonel Stapp did not take a high-speed ride on the track himself until he had been at Holloman almost a year. First he had to wait for the sled, known as Sonic Wind Number 1, which was specially constructed for his test program by Northrop Aircraft, Incorporated; then the sled and track equipment had to be put through a series of practice runs starting 23 November 1953. The first run with a living subject--a chimpanzee--took place on 28 January 1954.[9]

On 17 March, finally, Headquarters, Air Research and Development Command gave its authorization to conduct human runs;[10] and on 19 March, Colonel Stapp was strapped in for his first Holloman sled ride. Apart from testing the feasibility of the equipment for human experiments, the objective of Colonel Stapp's first ride was to "evaluate human reaction to exposure to about 15 g of linear deceleration for about 0.6 seconds duration, approximately double the duration possible for the same magnitude of force on the crash decelerator previously used at Edwards. . . ."[11] The run was essentially successful, reaching peak velocity of 615 feet per second and up to twenty-two g's deceleration, with only momentary ill effects.[12]

A second human experiment took place on 20 August, with Colonel Stapp again serving as subject. This test was primarily to explore the effects of abrupt windblast, which had not been a factor in the previous test because of a solid panel windshield installed on the sled. A special helmet was devised, completely covering the head, by Dr. Charles F. Lombard of Protection, Incorporated, a division of the Mine Safety Appliances Company. At the same time, to provide the abrupt exposure required, the sled was equipped with

> . . . .a rectangular frame holding two doors hinged to the sides which opened inward by outside

> wind pressure when a cam mounted at the selected point on the track tripped a mechanism releasing the catches. Abrupt impingement of windblast against the subject through the 34.5 by 62.50 inch opening thus provided would simulate the effect of jettisoning an aircraft canopy.[13]

This mechanism had first been tested with a chimpanzee run on 9 April, when only one door opened, but it had undergone additional tests since then, and on the 20 August run it functioned as scheduled. Colonel Stapp was exposed to an estimated maximum of 5.4 pounds per square inch of wind pressure, with maximum velocity of 736 feet per second and peak deceleration of only 12 g's. He suffered no apparent ill effects save temporary and quite minor injury from flapping clothes and windblown grains of sand. It was, he said, the "easiest" of all the runs he had made so far.[14]

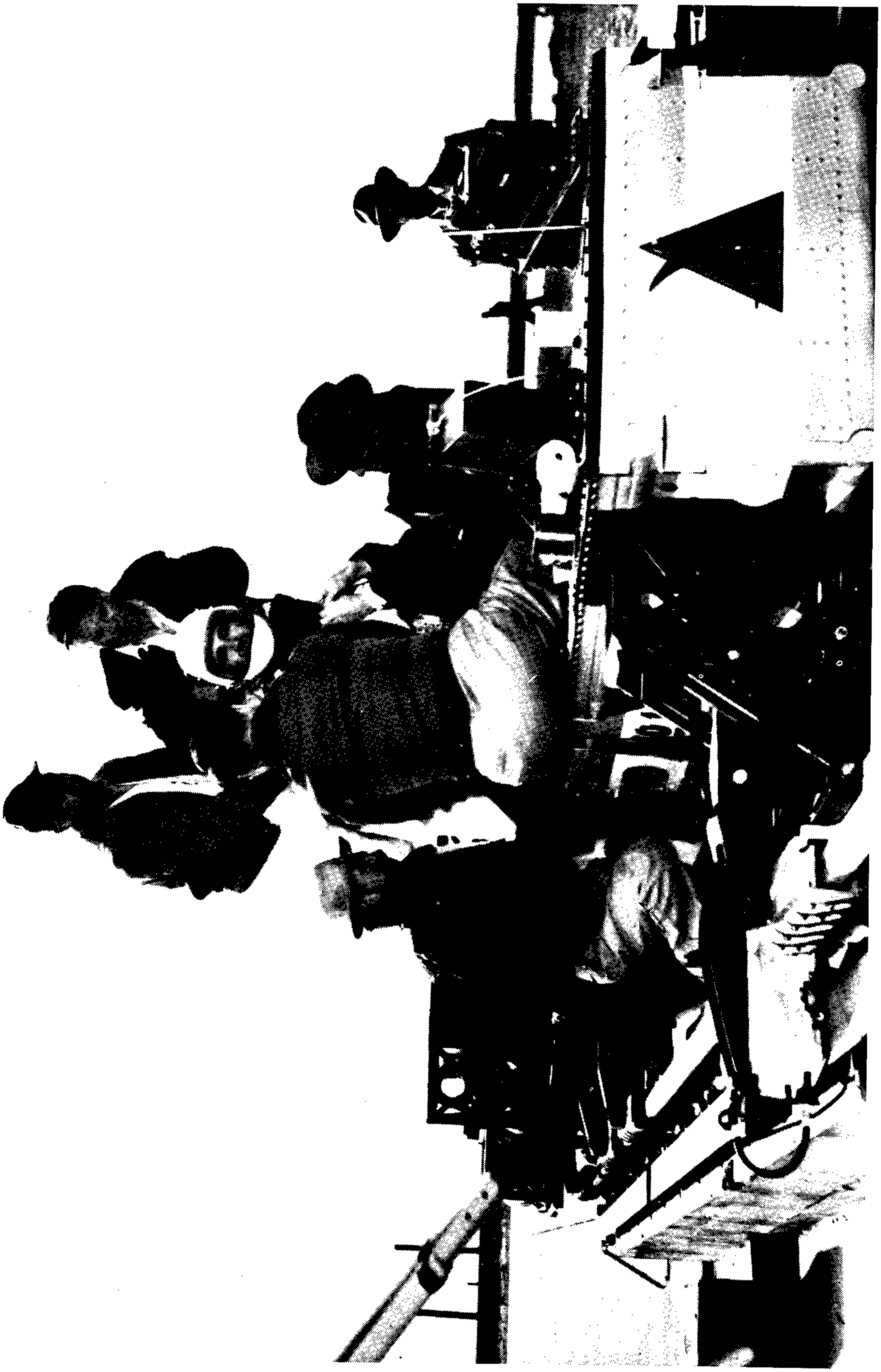
During September 1954, the principal sled experiment was one that made use of a tumbling seat attached to the rocket sled in order to evaluate the effect of tumbling in combination with deceleration and windblast. The tumbling seat had been tried out before in static tests, and in one preliminary test on a moving sled; but the first full-scale experiment was held on 14 September. A chimpanzee was spun at the rate of 105 revolutions per minute at the same time as it was being exposed to sudden windblast (through the same opening windshield used on Colonel Stapp's previous run) and to braking deceleration that reached a peak of forty-five g's; yet the subject came through very nicely.[15] This type of experimentation supplemented research done elsewhere on the effects of pure tumbling, for instance on a spinning turntable, but with its fixed axis of rotation the tumbling seat did not wholly simulate free-fall tumbling as encountered during escape from aircraft. Moreover, known instances of tumbling in the thin air at high altitudes all suggest that rapid tumbling must be eliminated if at all possible. And it largely can be, by means of stabilizing devices. For all these reasons the Aeromedical Field Laboratory has not continued its tumbling seat experiments, but instead continued work on deceleration and windblast both separately and in combination with each other.[16]

The month of September also saw the first testing, with a chimpanzee subject, of a new device for producing abrupt windblast--a windshield that could be jettisoned explosively at a given point during the run. Unfortunately, the jettisonable windshield inflicted quite a bit of damage on chimpanzees, causing the death of more than one, before this method finally proved its value.[17] During October, Colonel Stapp went to California, where he performed an autopsy on a Northrop test pilot believed to be the first person who had actually ejected from an aircraft at supersonic speed. For his own research on human tolerances, Colonel Stapp was interested to learn whether the pilot had suffered any major harm from windblast, tumbling, and deceleration. He could find none, concluding that the fatal injuries were due to being struck by the tail surface of the plane.[18]

Much of the activity of the Aeromedical Field Laboratory in the autmun of 1954 consisted of preparations--including chimpanzee control runs at 600 miles an hour and faster[19]--for the most memorable of all Colonel Stapp's rocket sled rides, the one of 10 December 1954. This test was designed to explore both deceleration and windblast, but there was no attempt to simulate abrupt onset of wind pressure. The jettisonable windshield was still unreliable, and the swinging-door system used in August weighed too much for the sled to attain desired velocity. Hence no windshield at all was used. Colonel Stapp merely wore the helmet he had used in August, completely covering his head, and saw to it, as before, that his arms and legs were well secured against flailing, which was one effect of windblast already known to induce injuries in actual escape from aircraft.

The run itself reached a maximum speed of 937 feet per second, or mach .9. This was fast enough for the sled to overtake and pass a T-33 aircraft that was flying overhead. Windblast was as high as 7.7 pounds per square inch, or better than 1,100 pounds per square foot, and water brakes brought the sled to a stop in just 1.4 seconds from maximum velocity. Rate of onset of deceleration was 600 g's per second, reaching a plateau of twenty-five g's and over for more than a second, with peaks of thirty-five and forty g's. The jolt Colonel Stapp received has been compared with that "an auto driver would experience were he to crash into a solid brick wall at 120 miles per hour."[20]

As was to be expected, this time Colonel Stapp showed much more obvious effects of his ride. There were some strap bruises and the usual blood blisters from grains of sand, but in addition he suffered extremely painful effects on the eyes. In



Colonel Stapp Preparing for 10 December 1954 Sled Run

Colonel Stapp's own words, on entry into the water brakes his vision became a "shimmering salmon," followed by "a sensation in the eyes. . .somewhat like the extraction of a molar without an anesthetic."[21] This one aspect of the experiment, which was due purely to deceleration and not to windblast, overshadowed all other minor injuries and physical sensations during and after the run. Yet not even the eyes suffered any long-range or irreversible damage. Colonel Stapp's experience left him with two black eyes, which lasted the usual length of time, but vision returned in about eight and a half minutes. To use his own words once again,

> There was no fuzziness of vision or sensations of retinal spasms as had been experienced in 1951 following a run [at Edwards] in which a retinal hemorrhage occurred. Aside from congestion of the nasal passages and blocking of paranasal sinuses, hoarseness and occasional coughing from congestion of the larynx, and the usual burning sensation from strap abrasions, there was only a feeling of relief and elation in completing the run and in knowing that vision was unimpaired.[22]

As soon as possible after his admission to the base hospital, where he went for further examination, Colonel Stapp "ate heartily and spent two hours accommodating demands of motion picture photographers making documentary coverage of the run."[23]

What the run proved, essentially, was that windblast on a properly secured and protected body at over 600 miles per hour and at 4100 feet above sea level--equivalent to mach 1.6 at 40,000 feet--[24] was "negligible and unnoticeable in comparison with deceleration effects of g-plateaus of more than 25 g's for 1.1 seconds."[25] This duration was the longest yet attained for such high g-forces, but the deceleration, too, was shown to be humanly tolerable. Moreover, it "exceeded any predicted g time pattern for high speed aircraft ejection."[26] Although acceleration effects were not a primary object of study, the run also demonstrated that acceleration exceeding six g's for more than three seconds, as attained in the first phase of the run, could produce brief visual blackout but again no serious injury--in fact nothing that would hamper a pilot exposed to similar thrust in high-speed catapult or jet-assisted takeoff from "taking over control of the aircraft within several seconds after launching."[27]

One other result of the 10 December experiment--and to a lesser extent of Colonel Stapp's two previous rides on the Holloman high-speed track--was to give the Air Force doctor a measure of popular renown as "the fastest man on earth" that was comparable to the esteem he already enjoyed among aeromedical scientists. His sudden emergence as a national hero led to a spate of television appearances, including one with Ralph Edwards' "This is Your Life," which required him to be mysteriously called away to Los Angeles from a conference he was attending on the east coast.[28] His portrait appeared on the cover of **Time,** and for obvious reasons it was news throughout the nation when the "fastest man" was cited by the Alamogordo, New Mexico, police for speeding at forty miles an hour (unspecified rate of onset) in a twenty-five-mile zone. However, the Justice of the Peace before whom he appeared managed to divert part of the publicity to himself by dismissing the charge against Stapp, issuing a new citation against a fictitious "Capt. Ray Darr," and paying the fine from his own pocket.[29]

Then, too, Colonel Stapp's famous ride was reproduced, in a fictional and somewhat romanticized version, as part of the Twentieth Century Fox motion picture "Threshold of Space." This picture was partially filmed at Holloman, where a number of special sled runs were staged in the fall of 1955 in cooperation with the film company. Likewise, an advance showing of the picture itself was held at the Holloman base theater, on 2 March 1956, with a collection of Hollywood stars imported for the occasion.[30]

On a more serious level, Colonel Stapp received many additions to his already substantial collection of honors and awards. Among these were the Air Force's own Cheney Award, granted yearly "for an act of valor, extreme fortitude, or self-sacrifice in an humanitarian interest performed in the preceding year. . .," which was personally given to him in August 1955 by General Nathan F. Twining, Chief of Staff. He also received an Oak Leaf Cluster to the Legion of Merit award he held before. An honorary Doctor of Science degree from Baylor University, his alma mater, was granted in May 1956 during the same ceremony in which an honorary degree was given to President Dwight D. Eisenhower. In November 1957, Colonel Stapp obtained the $1,000 Service Award offered by the Omaha Mutual Benefit Insurance Company, of which he was the third recipient. There were many other awards and citations, too, and of course

they were not based solely on the rocket sled experiments performed at Holloman in 1954. Colonel Stapp's achievements before coming to Holloman were naturally taken into account when he received professional or scientific recognition, and so was all his other work in directing the Aeromedical Field Laboratory since 1953.[31]

In some respects, national prestige was almost a disadvantage. Brigadier General Marvin C. Demler, Deputy Commander for Research and Development, Air Research and Development Command, at one point raised a "military objection" to Colonel Stapp's participation in a professional gathering on the ground that public appearances (both professional and otherwise) were causing "dissipation of his time into non-research and development efforts . . ." The message signed by General Demler counted sixty-two "known" appearances in roughly the first eight months of 1956.[32] Close contact with researchers elsewhere was, of course, extremely valuable for the Aeromedical Field Laboratory's program; yet Colonel Stapp himself calculated that in the second half of 1956 trips and appearances kept him away from the Laboratory for more time than he was actually present.[33]

Fortunately, Colonel Stapp managed somehow to proceed with his research despite such distractions. In fact he had scarcely recovered from his ride of 10 December 1954 before he was speaking of his desire to make another human experiment in the future at supersonic speed. What he had in mind was a sled ride at about 1,000 miles an hour, designed primarily to explore tolerance to windblast as such, rather than windblast combined with deceleration. Colonel Stapp suggested that a longer track would be needed both to develop such speed and to have enough room to come to a stop without the decelerative forces completely overshadowing those of windblast; and a likely candidate was the 4.1-mile "SNORT" or Supersonic Naval Ordnance Research Track at China Lake Naval Ordnance Test Station, Inyokern, California.[34]

However, Colonel Stapp has not yet taken his supersonic sled ride. He was even startled in June 1956 to read in the newspapers that he had been "grounded" from any future high-speed runs on the basis that he was too valuable for the Air Force to risk. The grounding statement was attributed to the same General Demler who shortly afterward "grounded" Colonel Stapp from attending a professional meeting. But in actual fact General Demler's remarks were somewhat overplayed in the press. Admittedly, command headquarters did not look with much favor on the possibility of another sled ride by Colonel Stapp, but he did not receive official notification of being "grounded,"[35] and he merely proceeded--as before--on the assumption that no further high-speed experiment with himself or any other human subject would be made without first carefully weighing all the advantages to be gained by it and receiving specific command approval. Until more preliminary tests were conducted, without human subjects, no concrete plans for another such human experiment could even be discussed.[36]

Chimpanzee tests, at any rate, have been continuing at regular intervals since December 1954. Within a week after Colonel Stapp's famous ride, a chimpanzee went down the Holloman high-speed track for another test of the jettisonable windshield, which this time failed to jettison at all. Early in the following year, a series of sled runs was held to explore the effect on chimpanzees of abrupt windblast in combination with forty-g deceleration for various durations. The stated objective was "to evaluate the exact transition point from purely impact effects to circulatory effects typical of centrifuge." Speeds were comparable to that attained by Colonel Stapp, and windblast effects were again negligible. The results also indicated that a chimpanzee could take forty g's for four-tenths second without critical injury, although they were inconclusive concerning longer exposure.[37]

Since the spring of 1955, both deceleration and windblast studies on the Holloman high-speed track have attained progressively higher values, but they have also followed increasingly separate lines of development. In the case of deceleration experiments, a number of sled runs were held from April through June 1955 with a drop seat mounted on the sled to explore the combination of vertical with horizontal deceleration. Windblast was not a serious factor in these tests, which were actually concerned with aircraft crash forces rather than high-speed escape. This type of experimentation will therefore be considered in a separate monograph related to other accomplishments in biodynamics at the Air Force Missile Development Center.[38]

Tests designed specifically for horizontal (transverse) deceleration were resumed on 31 August 1955 with another forty-g experiment. Later tests in Novem-

ber 1955 and March 1956 subjected chimpanzees to eighty g's of programmed deceleration, with rates of onset exceeding 4000 g's per second. Tests were then interrupted for about a half year, while the sled itself was reconstructed following an accident in which it became airborne, and also while the track was lengthened to 5000 feet. This extension was justified primarily for aeromedical research, was funded through an emergency allocation to the Aeromedical Field Laboratory and permitted the attainment of significantly higher speeds with even the relatively heavy sled Sonic Wind Number 1. Deceleration runs began again, on the 5000-foot track, in October 1956, and fifteen were conducted from then through the following March. Subjects were exposed to peak decelerations above 200 g's, with rates of onset ranging as high as 16,800 g's per second.[39]

These figures, obviously, far surpassed the limits of voluntary tolerance, and far surpassed any conceivable g-forces that might be encountered in high-speed escape from aircraft. Indeed, deceleration tests on the high-speed track since the summer of 1955 have been more concerned with pure research on deceleration forces than with any single applied research problem. Hence these experiments, too, will require further discussion in a later monograph.

Specialized Windblast Studies, 1955-1958

Even by the end of 1954, a significant amount of data had been accumulated on tolerance to the forces of wind-drag deceleration encountered in high-speed escape from aircraft. With the use of adequate restraint, these forces appeared humanly tolerable, to judge from Colonel Stapp's experiments, and escape system designers could plan accordingly. But it was not clear that the effects of windblast as such in high-speed escape would be similarly tolerable. Windblast encountered on Colonel Stapp's memorable ride did not even approach the maximum that might be expected in actual escape situations.[40]

The later deceleration runs from August 1955 through March 1957 did not use any sort of windshield, and therefore they also exposed test subjects to relatively high windblast. Once the track was lengthened, the deceleration sled reached velocities roughly as high as 775 miles an hour, or slightly over mach one.[41] Yet not even this increase in speed was enough to duplicate the maximum windblast possible in escape from high-performance aircraft. Certainly the windblast produced on these runs did not cause major ill effects, especially as the test subjects were well secured and used a type of face mask; in any case, windblast effects were bound to be overshadowed by the extreme g-forces experienced on the very same runs. Accordingly, as early as May 1955, the Aeromedical Field Laboratory began a series of tests carefully planned so that supersonic windblast as such, not deceleration, would be the primary interest. Unlike the later deceleration tests, these very clearly fell within the scope of research on high-speed escape from aircraft.

Specialized study of windblast effects was in accord with the April 1953 test directive for Biophysics of Abrupt Deceleration, which called for data on windblast alone as well as windblast in combination with deceleration. It was also foreshadowed by the theoretical organization of Project 7850, Biodynamics of Human Factors in Aviation, since a separate Task 78505, Tolerance to Abrupt Windblast, was included in the original project development plan. Major Joseph V. Michalski, who was also Chief of the Aeromedical Field Laboratory's Biodynamics Branch in 1954-1955, was listed as the original task scientist. Moreover, in the spring of 1955 the Laboratory received a new high-speed sled, Sonic Wind Number 2, which was specifically designed for windblast studies. It was lighter than Sonic Wind Number 1, and therefore capable of exploring windblast at supersonic speeds even within the original 3550-foot track length. Weight was saved by designing the sled for performance only at "25 g with a safety factor of 1.5."[42]

Fifteen runs were made at Holloman on the 3550-foot track with Sonic Wind Number 2 from 17 May 1955 through 2 March 1956. In three cases, anthropomorphic dummies rode the rails, but otherwise chimpanzee subjects were used. Tests were planned with ejectable windshield, with no windshield, and also (for certain sled-performance and control tests) with a fixed windshield. The top speed attained on a single run was 1445 feet per second, which was about mach 1.3 or just short of 1000 miles an hour. This happened to be a control run with fixed windshield, but on other runs, with animal subjects exposed to windblast, the sled reached velocities up to

roughly 1350 feet per second and encountered wind pressure well above 2000 pounds per square foot. This compared with 1107 per square foot sustained by Colonel Stapp in December 1954. It was also more than the estimated 1280 pounds per square foot encountered in February 1955 by test pilot George Smith, at mach 1.05 and 6500 feet, in the first definitely recorded instance of survival in supersonic escape. G-forces were comparable to or slightly greater than on Colonel Stapp's last ride, but the fixed-windshield control runs helped isolate any effects due solely to acceleration or deceleration forces.[43]

None of these experiments found what could be called a tolerance limit for windblast, much less the lethal point. Different chimpanzees suffered varying degrees of injury, mostly minor, depending on the type of harness and protective covering worn, but there was no indication that even the highest level of windblast experienced so far was necessarily injurious to a properly secured and protected subject. The next step was to develop still greater sled velocities, and the extension of the Holloman track to 5000 feet should have helped somewhat. However, the extension was not yet finished when still another construction project was started, this time designed to lengthen the facility to 35,000 feet, which would make it the longest in the world, and also to replace existing rails with continuous-weld track. The 35,000-foot track would not be ready for many months, and though the construction work did not at once put an end to test activities, it did seriously interfere with them. In these circumstances, Colonel Stapp and his associates simply transferred the windblast test operations (and the sled Sonic Wind Number 2) to the Supersonic Naval Ordnance Research Track at China Lake.[44]

Colonel Stapp's principal collaborator for the forthcoming China Lake tests was Doctor (Captain) John D. Mosely, who arrived at Holloman in the latter part of 1956 and was made Chief of the Biodynamics Branch as well as task scientist for Task 78505, Tolerance to Windblast. Captain Mosely's first windblast test, on 18 February 1957, was the first at China Lake and also the first high-speed track experiment since 2 March 1956 that was primarily designed for windblast. It was a checkout run, reaching a velocity of 1,333 feet per second. The first full-scale experiment came on 13 April, with very moderate acceleration and deceleration but a peak velocity of 1,945 feet per second (about mach 1.7). The chimpanzee subject wore a special flying suit devised by the Aeromedical Field Laboratory and a helmet developed by Protection, Incorporated. Unfortunately, the headrest failed even before the sled reached supersonic speed, the helmet failed in turn, and the head was yanked so violently as to break the subject's neck. There was some burned tissue due to windblast, but chiefly the run underscored the danger that exists from flailing if the subject is not adequately secured.[45]

The next run at China Lake was held on 27 June, and reached 1,905 feet per second, with a duration of two seconds at roughly mach 1.7. Maximum windblast was about 3,500 pounds per square foot. The test again resulted in the subject's death, but this time it occurred twenty-four hours after the run, and the cause was different. The chimpanzee was adequately secured against flailing, but helmet and clothing proved unsatisfactory; the flying suit tore and exposed the subject to serious burning from windblast. Roughly forty per cent of the body was covered with second and third degree burns. The chimpanzee at least fared better than certain guinea pigs attached to the same test sled by the Bio-Acoustics Branch of Wright Air Development Center's Aero Medical Laboratory. Two guinea pigs were attached merely with nylon netting, and the third was placed in a metal container whose largest opening measured one inch by two inches. The can itself stood up through the test, but all three guinea pigs vanished into thin air.[46]

Colonel Stapp and Captain Mosely were confident that just as the flailing that had lethal effect in April was prevented in June, the burning encountered in the June test could likewise be avoided. Dacron sail cloth used for strap material did not fail in the June run, suggesting that an entire suit made from the same cloth might provide the necessary protection. When the next test in the series took place on 12 March 1958--with speed and windblast about the same as before--a suit of the new material did prove satisfactory. Once again the subject was lost, because of a harness failure that in turn caused the helmet to come off, but it is hoped that this, too, will be prevented on the two remaining tests that are planned in the present windblast series.

On the last three tests, wind pressure still did not reach the highest levels con-

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ceivable in an operational escape situation. Even so, the levels attained are impressive, especially when it is kept in mind that for flight at higher altitudes than China Lake (elevation 2,218 feet) the air density and thus potential wind pressure for any given speed will naturally be less. It was even possible, in a sense, to take encouragement from the fact that damage from windblast was no worse. Then, too, some real progress has been made in devising means of protection, which further underscored the possibilities for adapting an open escape system, such as the ejection seat, for use with advanced supersonic aircraft. As Colonel Stapp has pointed out, the greatest advantage of a completely enclosed system --that is, of an escape capsule--is simply the elimination of windblast, since the problems of tumbling and deceleration must be met in either case.[47]

To be sure, not everyone agrees with this line of reasoning, and more will be said on the arguments for and against different escape systems toward the end of this study. However, it was not the role of the Aeromedical Field Laboratory to dictate the design of escape systems. Its role was to provide experimental data on which final decisions could be based, and from this standpoint the windblast experiments will have fulfilled their objective no matter what the final test results may be.

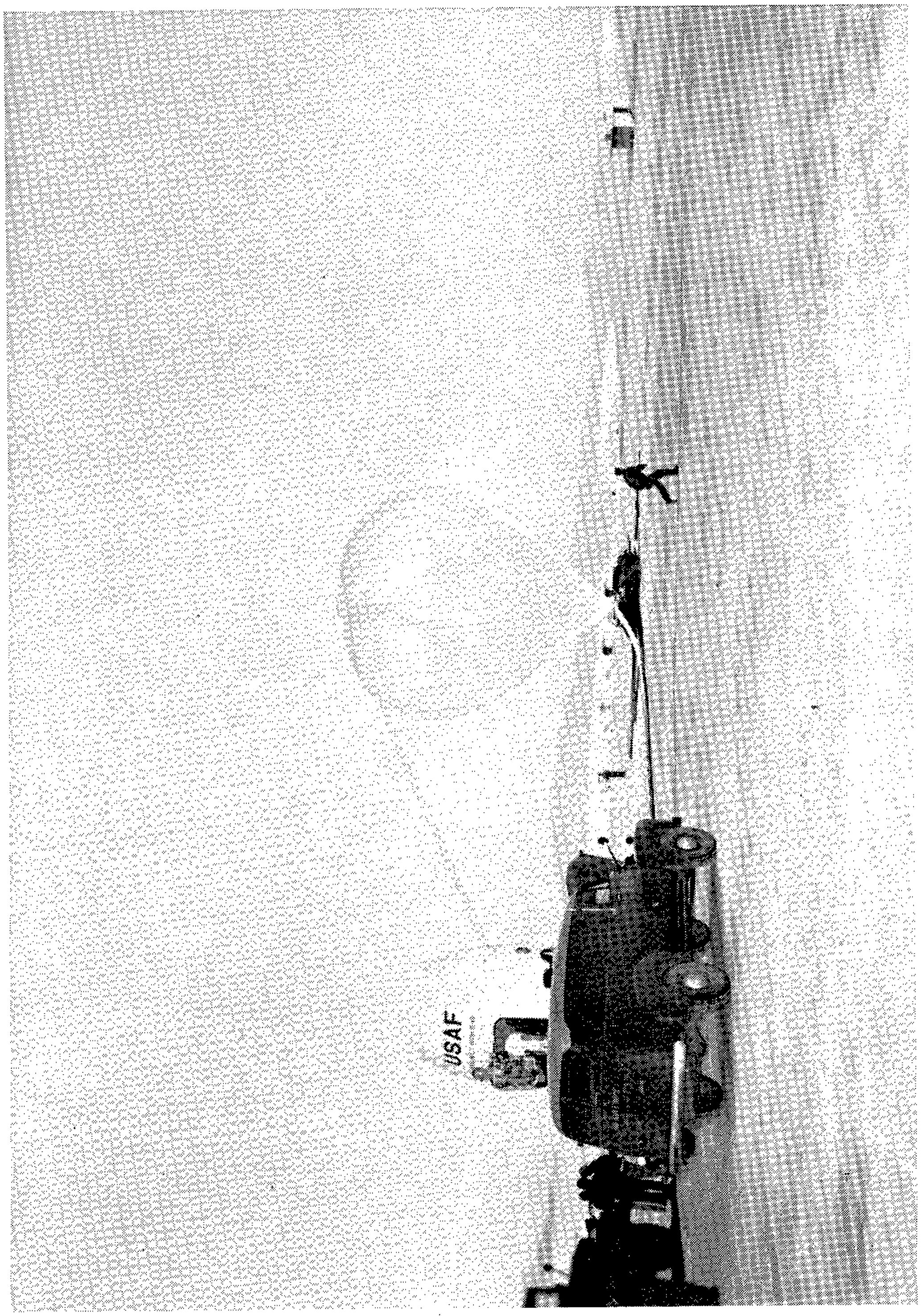
It is worth noting that the Holloman laboratory received excellent cooperation from the Navy for its series of China Lake sled runs. When unexpected delays arose during preparations for the June 1957 run, certain tests relating to high-priority missile development were temporarily "bounced" in order to hold the track for the Aeromedical Field Laboratory. On the other hand, operations at China Lake could be a rather expensive proposition. Quite apart from the cost of moving people, equipment, and chimpanzees to California, Colonel Stapp had been quoted an estimate of $75,000 for use of the Navy track on five test runs; but the first run alone took more than a third of this amount. Because of bookkeeping technicalities, the second run, on 13 April 1957, was much cheaper even though it happened to fall on a Saturday. Weekend testing required payment of overtime to employees but did not saddle the Air Force with a large share of base overhead.[48]

For various reasons, the March 1958 run was cheaper still--but it will be the last at China Lake. The remaining tests in the current series will be conducted on the newly-completed 35,000-foot track at Holloman. They will also be conducted by Captain Mosely without the assistance of Colonel Stapp, unless he returns for the occasion from Wright Air Development Center, where he went to assume direction of the much larger Aero Medical Laboratory in April 1958.

After that, the task program will continue to use the local test facilities, but it will undergo a definite reorientation. The windblast task of Project 7850 (Task 78505) has been renamed Tolerance to Ram Pressure and Thermal Effects in line with the general revision of Project 7850, which is now entitled Biodynamics of Space Flight. Thus in future the problem of escape from aircraft--meaning principally escape from high-performance aircraft at low or medium altitude--will no longer be the primary concern of Task 78505. The latter will have more to do with problems of flight through the upper atmosphere (120,000 feet or higher) and in space, including emergency escape from a manned vehicle re-entering the atmosphere.[49]

Other Work on the Escape Problem

Although high-speed track studies of windblast and deceleration have been the main Holloman contribution to research on the escape problem, they do not represent the Center's entire effort. Another unique Holloman facility that has been used for this research is the 120-foot short track, or Daisy Track as it is usually called. This track was completed in 1955, precisely for aeromedical research, and is operated under the general auspices of Task 78503 (of Project 7850), Tolerance to Impact Forces. The Daisy Track is a versatile research tool, and its performance range has nicely supplemented that of the more famous long track. The majority of the work related to its use will be described in detail in a later monograph, since its purpose is to accumulate basic research data on human tolerance to as broad as possible a range of g-forces, in all planes of body orientation, rather than to support a particular program of applied research. However, data acquired on the Daisy Track are relevant to a great many specific research problems, of which not the least has been the problem of escape from aircraft. From the viewpoint of anyone who must deal with that problem, obviously, the more data become available on g-tolerances, the less room there is for guesswork in what is a matter of life or death.



Project High-Dive Dummy Launch

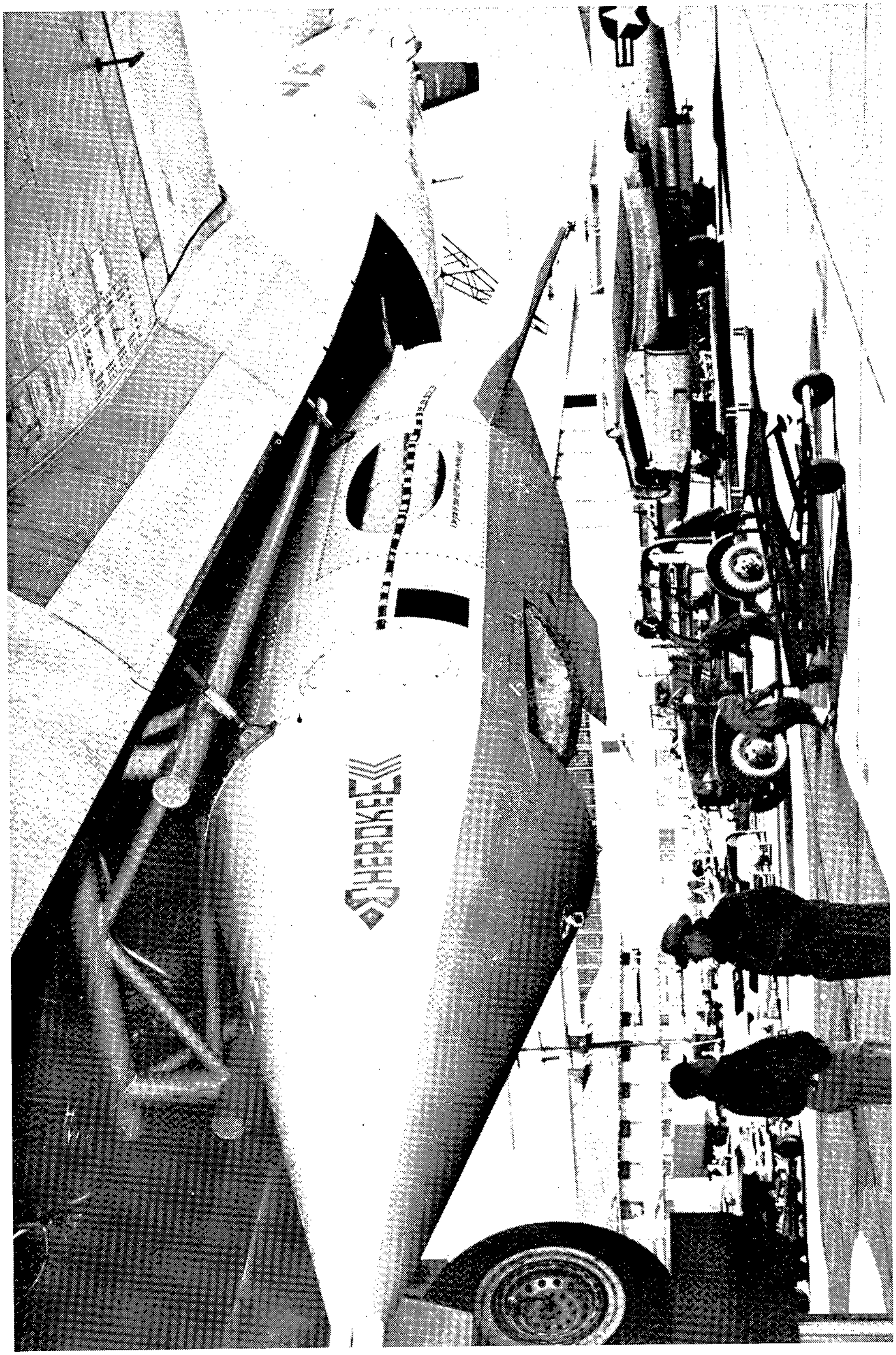
Colonel Stapp's experiments on the long track supplied data on tolerance to deceleration such as a pilot encounters from wind drag following actual ejection from the aircraft, but Daisy tests--to cite one concrete example--have added information on tolerance to the g-forces involved in propelling the ejection seat itself (or other escape device) out of the aircraft. To clear the high-flying tail of modern jet planes a powerful thrust is needed, and therefore both Air Force and aircraft industry representatives have been interested to learn that human volunteers on the Daisy Track have sustained slightly over thirty g's in a position for upward ejection (g-forces parallel to the spine) with no lasting ill effects. It had formerly been thought that anything above twenty-four g's in this position threatened spinal injury, but designers now appear to have a little more leeway. The Daisy Track has also been used to explore g-tolerances in the special position assumed for riding the experimental Convair "B" ejection seat which is discussed below. And it has been used in certain cases to test new harness designs and other specific items of equipment, both for crash restraint and for actual escape from aircraft.[50]

A somewhat different type of research, though still related to escape from aircraft, was conducted by Colonel Stapp in April 1957 amid the dunes of White Sands National Monument, which is wholly surrounded by the Holloman-White Sands Proving Ground integrated test range. The aim was to explore the possibility of remaining fastened in an ejection seat throughout parachute descent. For this purpose, a human subject would take his place in an ejection seat, which in turn was attached to a small plastic balloon; he then rose up in the air a short distance and came down with the balloon itself taking the place of a parachute. Impact velocities gradually increased until they began to approach standard parachute-landing speeds. Volunteer participants in these tests reported some discomfort, but it was agreed that the procedure was well worth exploring further.[51]

In addition to the research efforts of its own Aeromedical Field Laboratory in the area of escape from aircraft, the Air Force Missile Development Center has collaborated in related efforts by the Aero Medical Laboratory at Wright Field. One example is the "manned balloon flight" program that was made a task of Wright Air Development Center's Project 7218, Biophysics of Escape (now replaced by Project 7222: Biophysics of Space Flight), and is often referred to by the short title High-Dive. This program actually dates back to the period when Colonel Stapp was previously assigned to Wright Field, before coming to Holloman, and it was then regarded as a "first step in the development of a floating laboratory for a variety of upper atmosphere studies."[52] However, a more immediate objective was to have human subjects stage experimental parachute jumps from balloon gondolas at altitudes ranging up to approximately 100,000 feet, and this objective was of obvious importance for aircraft escape procedures.

Colonel Stapp not only helped in the preliminary planning for this program while he was at Wright Field but continued to follow its development with interest after his arrival at Holloman. Other officers of the Aeromedical Field Laboratory were also interested, lending their cooperation when needed. The chief concrete support rendered at Holloman, however, came from the local Balloon Branch, which had the task of conducting balloon flights for the Wright Field project. The first launch attempt, on 1 May 1953, was unsuccessful, but launchings continued intermittently thereafter. Flights were made to test balloon performance, parachute equipment, and gondola systems; and anthropomorphic dummies took practice jumps for various purposes, accumulating data on free fall or exploring the characteristics of stablizing parachutes. A few launches were made in the fall of 1955 on behalf of Twentieth Century Fox, which included a Hollywood version of this project in the same motion picture, "Threshold of Space," that featured Colonel Stapp's sled rides.

Project High-Dive also encountered numerous delays, however, and the proposed manned balloon flights have not yet taken place. One of two balloon gondolas developed for the project was appropriately named "[On-Again, Off-Again] Finnegan." Project officers came to Holloman Air Force Base in the fall of 1957 for another series of dummy tests leading up to the actual live bailouts; but before much else was accomplished there was a change of plan in order to provide experimental testing of an escape system developed for the X-15 rocket aircraft. There has also been a change of name, from "High-Dive" to "High-Chair." In effect, the special X-15 ejection seat and allied parachute equipment will be dropped in various tests from a stratosphere balloon, and in the scheduled manned experiment from 97,000 feet the test subject is to ride all the way up in the seat itself rather than in a balloon



Cherokee Missile Used in Project Whoosh

gondola. What else may finally develop out of the Aero Medical Laboratory's manned-balloon program remains a matter of conjecture. Meanwhile, Holloman's own Project Man-High, as described in an earlier monograph, has definitely taken the lead as far as creation of a balloon-borne "floating laboratory" is concerned.[53]

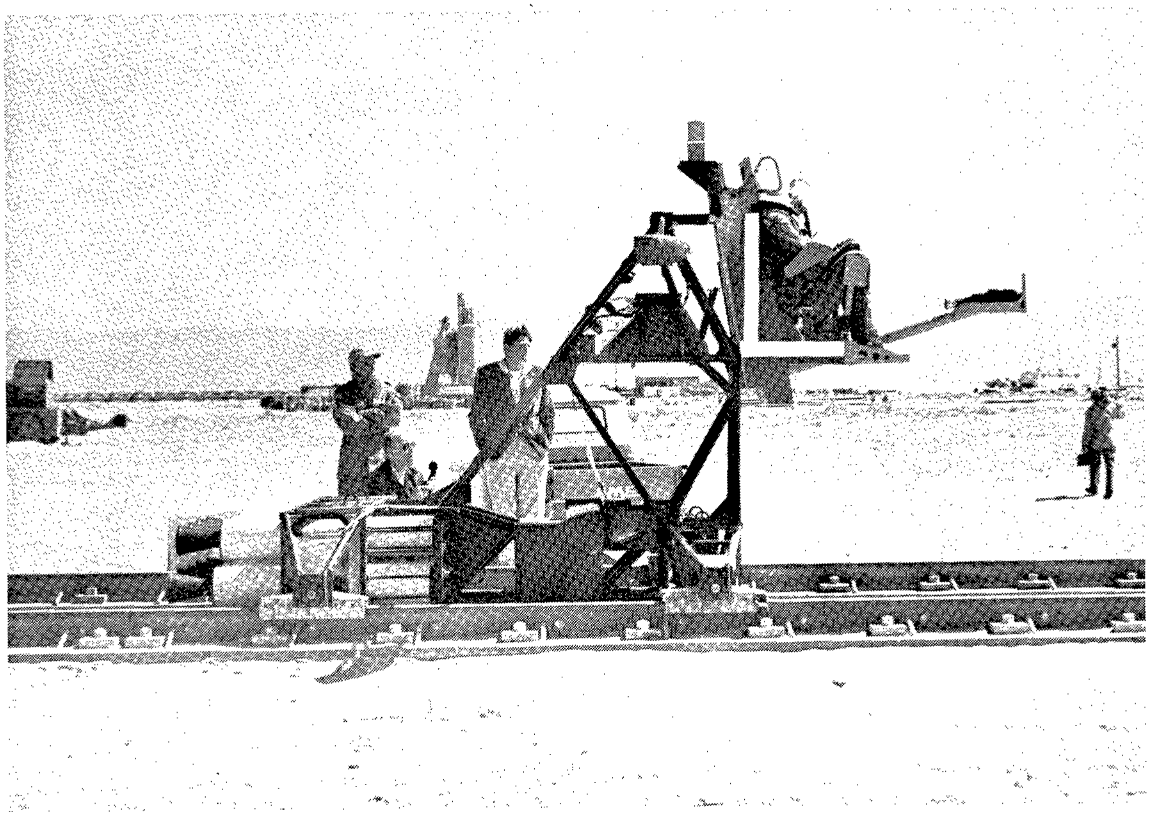
Still another cooperative venture between Holloman and Wright Field with a direct application to the escape problem was Project Whoosh, which aimed to "evaluate escape from a high speed aircraft at approximately Mach 2."[54] The project involved ejection of chimpanzee subjects, from a specially-designed Cherokee missile. The missile was to be taken aloft by a modified B-29 bomber and then accelerated to supersonic speeds before the anesthetized subject, strapped into an open ejection seat, was shot out from the missile's interior. Direction of this activity was assigned principally to the Aero Medical Laboratory at Wright Field, where it became another aspect of Project 7218, Biophysics of Escape, but Colonel Stapp and others at Holloman participated extensively. The Aeromedical Field Laboratory supplied chimpanzees, and Holloman Air Force Base was the site for several of the actual tests.[55]

The first two live ejections took place at Edwards Air Force Base, California, on 26 January and 8 June 1954, at speeds of mach 1.1 and mach 1.5. Then, in 1955, all testing activity shifted to Holloman, where superior range instrumentation and chimpanzee quarters were available. Two low-speed control studies were made in July, dropping seat and subject from a C-47, without benefit of Cherokee missile. They were followed by two more supersonic ejections on 21 October 1955 at mach 1.5 and 3 April 1956 at mach 1.4, both times bringing the project B-29 (which happened to be the X-1 mother ship) all the way from Edwards at considerable cost in time and overhead. Problems of coordination were multiplied several times over for the last test by confusion and misunderstandings at command headquarters, Wright Field, Holloman, and Edwards as to whether the entire project was or was not being cancelled. It was cancelled beyond any doubt soon after the final Holloman test. Not one of the animals ejected at supersonic speeds had managed to survive, for in each case there were equipment difficulties (with parachute system or ejection seat) that led to death of the subject and overshadowed any possible evidence of injury through supersonic windblast, tumbling, and deceleration. Nevertheless, the project was not a total loss. Even the failures were instructive, and the work performed on Whoosh led directly to further ejection experiments at the Supersonic Military Air Research Track, Hurricane Mesa, Utah.[56]

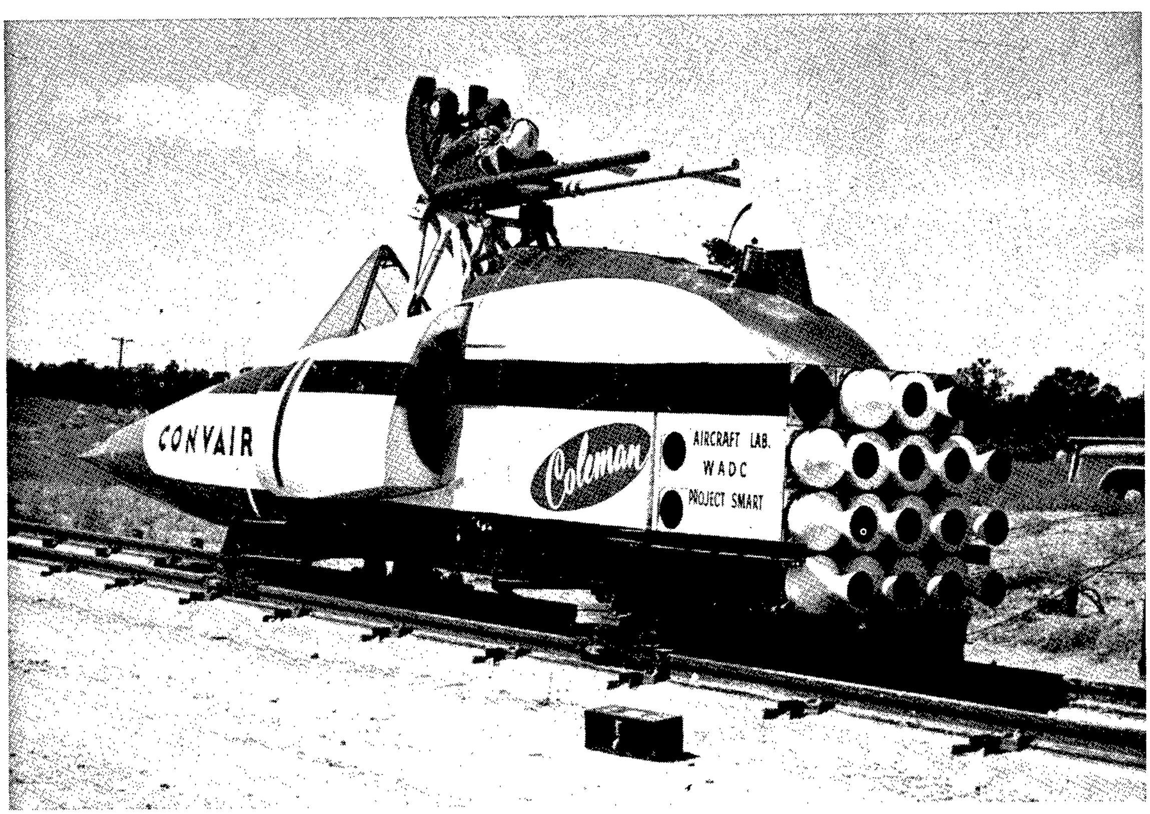
This last track is an off-base facility of Wright Air Development Center and is especially well suited for tests of escape systems. The track leads straight to the edge of a cliff, and objects fired from a supersonic sled are then lowered by parachute to the canyon floor 1,500 feet below. In a sense, Whoosh operations were simply transferred from mid-air to the track at Hurricane Mesa, with the Aeromedical Field Laboratory still supplying chimpanzee subjects and still taking a direct interest in the proceedings. During the fall of 1956, five chimpanzee subjects were ejected at speeds of about mach one, using a special ejection seat designed for testing rather than for operational use, and three were recovered uninjured. These successful ejections ranged from .95 to 1.15 mach. In March 1957, a chimpomorphic dummy was ejected successfully at mach 1.1, but the next attempt in the series, again using a chimpanzee, was unsuccessful; in fact the sled itself was wrecked.[57]

Meanwhile two members of the aircraft industry, Lockheed and Convair, have been making significant progress with improved ejection seats of unusual design. Each has been specially commissioned to do so, on behalf of the industry as a whole, by the Industry Crew Escape Systems Committee. The Lockheed seat, intended for downward ejection, uses a skip-flow generator somewhat resembling the small bug-deflecting devices often mounted on the hood of automobiles. In Colonel Stapp's words, this "ingeniously surrounds the escapee with an atmospheric capsule, and is an impressive device to extend the range of the ejection seat." In April 1957 this experimental Lockheed system was tested on the Holloman high-speed track, and it has also been tested (with anthropomorphic dummies) at Hurricane Mesa.[58]

The Convair "B" seat, which is designed for upward ejection, is chiefly distinguished by the telescoping booms that are extended during the ejection process and give the seat a remarkable stability in the air. It is lifted to a horizontal position atop the plane before being fired into the airstream; the pilot then rides feet-first, with knees tucked up and with the rounded bottom of the seat giving added protection. This seat, too, has been track-



Test of Lockheed Ejection Seat on Holloman Track



Convair "B" Seat Mounted for Track Testing

tested, at Hurricane Mesa and at Edwards Air Force Base. It is one of the most promising of all recent escape devices, although naturally the maneuver of raising the seat into position for firing from a crippled aircraft poses some rather complex problems. However, work toward solving these and other problems has been going ahead on several different fronts. One such front is the Aeromedical Field Laboratory, where tests on the Daisy Track have clearly established human tolerance for the predicted g-forces in the exact body position required for riding the Convair seat.[59]

Seats and Capsules: Conflicting Views of Escape

Colonel Stapp warmly welcomed all recent successes in the testing and development of open (seat-type) escape systems, not only because of the intrinsic importance of these events but also because they appeared to support his own views on the relative merits of different escape devices. For Colonel Stapp has been outspoken in the belief that open systems, with technical improvements in the current models of seats and personal equipment, can continue for some time to meet most requirements for escape from high-performance aircraft. In his opinion, both his own research findings as to windblast and deceleration and the latest developments in seat design tend to confirm the usefulness of the ejection seat for supersonic escape. Referring to certain tests of the new Convair seat, he remarked with a measure of rhetorical exaggeration that they were "causing acres of grey hairs among the precocious proponents of the capsule."[60]

Not all those proponents have yet come around to Colonel Stapp's viewpoint (which is generally shared by Captain Mosely also). In fact a large body of thought both inside and outside the Air Force has held for some years that the ejection seat is obsolete for late-model aircraft and that an enclosed capsule system must take its place as quickly as possible. Such a system, it is argued, can offer full protection from windblast; lessen the rate of deceleration through streamlining, though increasing the duration of decelerative forces at the same time; enhance flying comfort by eliminating requirements for elaborate protective clothing (the "T-shirt concept of flying"); and serve as boat or igloo for any pilot forced to eject over water or on Arctic wastes. Those who take this view, while emphasizing the basic research value of data developed by the Aeromedical Field Laboratory on windblast and deceleration, profess some doubts as to whether the forces tolerated by Colonel Stapp and assorted chimpanzees in high-speed track experiments would necessarily be tolerable to pilots in operational escape situations. T-shirt enthusiasts, in particular, feel that the required amount of protective harnessing would not always be practical. Finally, supporters of the capsule system recognize that the experimental Convair seat incorporates some of the advantages that a capsule offers, but they are not yet wholly convinced it will work, and they insist that while it might somewhat extend the operational capability of the ejection seat, it cannot take the place of a true capsule.[61]

The idea of the capsule system can be traced back roughly as far as the ejection seat itself, to German developments during World War II. The German DFS-228 aircraft had a detachable nose that essentially served as a capsule to bring the pilot down to lower speed and altitude, where he could make his definitive escape by parachute. In the United States, both the Navy and Air Force began active study of capsule systems after the war, and the Bell X-2 rocket plane was equipped with a capsule escape system that was basically designed as far back as 1946. From 1947 to 1952 the Air Force, to avoid duplication of effort, left the major part of United States capsule research to the Navy, while concentrating on seat-ejection improvements, but in 1952 Air Research and Development Command put the Air Force back into full-scale study of capsule escape.[62]

This renewed Air Force interest in capsules bore fruit in July 1956, when the Directorate of Engineering Standards at Wright Air Development Center revised the **Handbook of Instructions for Aircraft Designers** in such a way that manufacturers were frankly urged to provide capsules rather than ejection seats for aircraft "capable of speeds in excess of 600 Kts. EAS or altitudes in excess of 50,000 feet." The capsule was not made absolutely mandatory, but the wording of the revised **Handbook** showed a strong preference, which was also the preference of Lieutenant General Thomas S. Power, Commander of Air Research and Development Command, and of certain other high officers both of the Command and of Wright Air Development Center. Moreover, circular letters were dispatched to aircraft companies at the same time, calling their attention to the new

Handbook and in particular to the indicated preference for capsule escape.[63]

These developments distressed Colonel Stapp. He felt, first of all, that no firm decisions on escape systems should be made until all relevant data had been gathered; and his own studies of supersonic windblast, in particular, were still incomplete. Nor was he overly impressed with the stated advantages of the escape capsule. In answer to the much-discussed comfort factor, he stated that "you can't build a weapon around a rocking chair just because a rocking chair is comfortable,"[64] and he has pointed out that the capsule also has its own disadvantages. These include the larger target area offered by a capsule when used in combat; the difference in cost, with capsules likely to be at least five times more expensive than improved supersonic ejection seats; and a great many technical complications, especially for low-altitude escape, which match or exceed the complications involved in firing the experimental Convair seat.

There are things that can go wrong with the capsule itself after separation from the aircraft, so that it would still be wise to have a pressure suit handy, and ideally (in Colonel Stapp's words) to build in "an escape system for an escape system."[65] In this connection, he has observed that the one recorded case in the United States Air Force of attempted capsular escape, in the X-2, was unsuccessful: the pilot managed to detach the capsule from the aircraft but the main capsule parachute failed to open, and the pilot was for some reason unable to abandon the capsule itself before impact.[66] By contrast, supersonic survival with an open escape system has actually taken place. The first man definitely known to have accomplished this feat, test pilot George Smith, suffered severe injuries, but these were due apparently to "high decelerative and rotational forces," sustained in unfavorable body position and with inadequate harnessing. There is no indication that they were due to windblast as such, the one mechanical force against which a capsule, unlike an open seat, can offer complete protection.[67]

The official preference for capsules, as expressed in the **Handbook of Instructions for Aircraft Designers,** still stands. In practice, however, capsule development is not yet far enough advanced for much to be done about implementing that preference. Thus, for the present, supersonic aircraft--even the X-15--will continue to be produced with open escape systems. Indeed the **Handbook** revision was no sooner made than the Air Force itself set in motion the program of industry-wide cooperation whereby Lockheed and Convair received primary responsibility for devising improvements in downward and upward ejection seats respectively.[68] Even with these improvements, the performance capability of the open escape system is obviously limited--but so is that of an escape capsule. The difference is one of degree, and the point at issue has been essentially a matter of timing, concerning just how much useful life there still is in open escape sytems before they are written off as obsolete.

As a matter of fact, neither the Convair "B" seat nor any escape capsule so far envisaged would be of much use for bailing out of a spaceship midway between Earth and Mars. Nevertheless, much of the research so far accomplished on escape physiology at Holloman and elsewhere has a direct significance for manned space flight. The most obvious example is the applicability of data on g-tolerances acquired from Colonel Stapp's Holloman sled rides to the coming problems of rocket acceleration and deceleration. Those same sled rides, along with other rocket-track experiments on windblast and deceleration, formed the point of departure for the development at Holloman of research efforts on a broad range of biodynamics problems to be treated in a subsequent monograph. And, needless to say, they will long be remembered among the dramatic highlights in the history of the entire Air Force Missile Development Center.

NOTES

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2. "Research Program, Escape From High Performance Aircraft." Report prepared in Aeromedical Field Laboratory, ca. November 1954.

3. Cf. Col. John P. Stapp, "Reorganization of Administration of Applied Research and Development in Human Factors in Aircraft," study submitted to Col. C. H. Roadman, summer 1957.

4. Cf. ARDC Test Directive 5200-H2, Biophysics of Abrupt Deceleration, 25 October 1954.

5. Address delivered to National Safety Forum, fall 1955.

6. Major John P. Stapp, **Human Exposures to Linear Deceleration. Part I. Preliminary Survey of the Aft-Facing Seated Position** (AF Technical Report 5915, Part I, WADC, 1949), p. iii; Stapp, **Human Exposures to Linear Deceleration. Part II. The Forward Facing Position and the Development of a Crash Harness** (AF Technical Report 5915, Part II, WADC, 1951), pp. iii, 16-20; Stapp, **Human and Chimpanzee Tolerance to Linear Deceleration Forces** (n.d.), p. 9; address by Col. Stapp at Texas Technological College, Lubbock, 3 October 1955.

7. Address by Col. Stapp at Texas Technological College, 3 October 1955.

8. Lt. Charles E. Wilson, Jr., "The Holloman High Speed Track" (1956); **The Holloman Track** (AFMDC Technical Report 57-1, September 1957).

9. Ltr., Lt. Col. John Paul Stapp, Chief, Aeromedical Field Laboratory, to Col. A. P. Gagge, Chief, Human Factors Division, Directorate of R & D, Hq., USAF, subj.: [Holloman Sled Experiments], 12 March 1954; interview, M/Sgt. James F. Ferguson, Aeromedical Field Laboratory, by Dr. David Bushnell, AFMDC Historian, 19 November 1957.

10. **History of Holloman Air Development Center, 1 January to 30 June 1954,** p. 88.

11. Lt. Col. John P. Stapp, "Effects of Mechanical Force on Living Tissues I. Abrupt Deceleration and Windblast," **Journal of Aviation Medicine,** Vol. 26, pp. 273 (August 1955).

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13. **Ibid.,** p. 275.

14. Stapp, "Effects of Mechanical Force on Living Tissues I," **Journal of Aviation Medicine,** Vol. 26, p. 277; **History of Holloman Air Development Center, 1 January to 30 June 1954,** pp. 88-89; Aeromedical Field Laboratory, "Monthly Historical Report," August 1954.

15. "Project 91 - MX - 981 - Aero Med Sled Run Data--Holloman Track," Issue III, 1 May 1957; Project Abrupt Deceleration, **Weekly Test Status Report,** 14 September 1954.

16. Aeromedical Field Laboratory, "HADC Semi-Annual Progress Report [on Abrupt Deceleration]," July-December 1954; Lt. Col. John P. Stapp, "Human Tolerance to Deceleration," **American Journal of Surgery,** Vol. 93, p. 739 (April 1957); Stapp, "Human Tolerance Factors in Supersonic Escape," **Journal of Aviation Medicine,** Vol. 28, p. 79 (February 1957); **History of Holloman Air Development Center, 1 July to 31 December 1954,** p. 98.

17. Project Abrupt Deceleration, **Weekly Test Status Report,** 16 September and 26 October 1954, 8 February 1955.

18. **Ibid.,** 26 October 1954.

19. **Ibid.,** 23 November 1954.

20. Stapp, "Effects of Mechanical Force on Living Tissues I," **Journal of Aviation Medicine,** Vol. 26, pp. 277, 278; **Alamogordo Daily News,** 28 December 1954. The brick-wall comparison is quoted from a speech by Lt. Gen. Samuel E. Anderson, Cmdr., ARDC (at a meeting of the American Rocket Society, Dallas, Texas, 19 March 1958).

21. Stapp, "Effects of Mechanical Force on Living Tissues I," **Journal of Aviation Medicine,** Vol. 26, p. 280.

22. **Ibid.,** p. 281.

23. Project Abrupt Deceleration, **Weekly Test Status Report,** 14 December 1954.

24. Stapp, "Effects of Mechanical Force on Living Tissues I," **Journal of Aviation Medicine,** Vol. 26, p. 286.

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26. Aeromedical Field Laboratory, "HADC Semi-Annual Progress Report [Abrupt Deceleration]," July-December 1954.

27. Stapp, "Effects of Mechanical Force on Living Tissues I," **Journal of Aviation Medicine,** Vol. 26, pp. 280, 284, 285.

28. Various ltrs., referring to the event, in Col. Stapp's correspondence file, Aeromedical Field Laboratory.

29. **Time,** 12 September 1955; **Alamogordo Daily News,** 9 March 1956.

30. **Test Report (Interim Status) on "The Threshold of Space,"** No. 1, 24 October 1955; **Alamogordo Daily News,** 4 March 1956.

31. **Alamogordo Daily News,** 26 August and 25 November 1955, 1 June 1956; **Holloman Rocketeer,** 8 November 1957. The description of the Cheney Award is quoted from **The United States Air Force Dictionary** (Air University Press, 1956), p. 112.

32. 1st ind., Brig. Gen. Marvin C. Demler, Dep. Cmdr./R & D, ARDC, to basic ltr., Hq., USAF, subj.: "Meeting of Joint Committee on Aviation Pathology," 27 August 1956.

33. Ltr., Col. Stapp to Maj. Rufus R. Hessberg, Jr., Chief, Biophysics Branch, Aero Medical Laboratory, WADC, subj.: [Windblast tests], 2 January 1957.

34. **Alamogordo Daily News,** 29 December 1954, 4 January 1955.

35. **Alamogordo Daily News,** 17 June 1956.

36. Ltr., Col. Stapp to Col. John M. Talbot, Chief, Human Factors Division, Hq., ARDC, subj.: [Human Sled Runs], 25 June 1956.

37. Project Abrupt Deceleration and Project 7850, **Weekly Test Status Report,** 21 December 1954, 8, 15, and 22 February 1955, 8 and 22 March 1955; Aeromedical Field Laboratory, "HADC Semi-Annual Progress Report [Abrupt Deceleration]," July-December 1954.

38. **Research Accomplishments in Biodynamics: Deceleration and Impact, at the Air Force Missile Development Center . . . 1955-1958** (to be published 15 July 1958).

39. "Project 91 Performance Data," 5 July 1957, chart in library of Aeromedical Field Laboratory; Aeromedical Field Laboratory, "Semi-annual Progress Report. . .Project 7850," 1 January-30 June 1955; Test Facilities Division, HADC, "Historical Report," 1 January-31 March 1956; photostats of test data, high-speed track runs of January-March 1957, in files of Biodynamics Branch; "Chimpanzees Pass Space Speed Test," **New York Times,** 31 January 1958.

    This track extension to 5,000 feet was intended not only to permit higher sled performance but also to enhance the safety of track operations. On some earlier tests the rockets were still burning when the sled entered the water brakes, which was hard on the sled itself and dangerous to the test subject (ltr., Col. Clarence L. Elder, DCS/O, HADC, to Cmdr., ARDC, subj.: "Holloman Air Development Center Annual Progress Report," 31 July 1954).

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41. "Project 91 Performance Data," 5 July 1957.

42. Lt. Col. John P. Stapp and Capt. C. D. Hughes, "Effects of Mechanical Force on Living Tissues II. Supersonic Deceleration and Windblast," **Journal of Aviation Medicine,** Vol. 27, pp. 407-408 (October, 1956); RDB Project Card, Biodynamics of Human Factors in Aviation, 23 April 1954.

43. "Project 91 Performance Data," 5 July 1957; Stapp and Hughes, "Effects of Mechanical Force on Living Tissues II," **Journal of Aviation Medicine,** Vol. 27, p. 413; ltr., Col. Stapp to Maj. Rufus R. Hessberg, Jr., Chief, Biophysics Branch, Aero Medical Laboratory, WADC, subj.: [Windblast Experiments], 2 January 1957; Stapp, **Escape from Aircraft** (n.d.), p. 3.

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45. Aeromedical Field Laboratory, "Historical Data. . .1 April-30 June 1957," p. 6; interview, Col. Stapp by Dr. Bushnell, July 1957.

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47. Cf. Lt. Col. John P. Stapp, "Human Tolerance Factors in Supersonic Escape," **Journal of Aviation Medicine,** Vol. 28, pp. 77-82 (February 1957); interview, Col. Stapp by Dr. Bushnell, July 1957; interviews, Capt. John D. Mosely, Chief, Biodynamics Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 19 March and 9 April 1958.

48. Notes at China Lake, 27 June 1957; interview, Col. Stapp by Dr. Bushnell, 7 March 1958.

49. R & D Project Card (DD Form 613), Biodynamics of Space Flight, 19 March 1958, pp. 6, 7; interview, Capt. Mosely by Dr. Bushnell, 9 April 1958.

50. Center staff briefing by Capt. Eli L. Beeding, Task Scientist, Tolerance to Impact Forces, 29 October 1957; interview, Capt. Mosely by Dr. Bushnell, 2 December 1957; Aeromedical Field Laboratory, "Historical Data. . .1 January through 31 March 1958," p. 12.

51. Interview, Mr. Bernard D. Gildenberg, Chief, Technical Support Section, Balloon Branch, AFMDC, by Dr. Bushnell, 23 January 1958; ltr., Col. Stapp to Mr. C. W. Alston, Flight Test Engineer, Convair Division of General Dynamics Corporation, Edwards, California, subj.: [Balloon Flights at White Sands National Monument], 18 April 1957.

52. Aero Medical Laboratory, WADC, "History. . .1 July 1952 to 1 January 1953;" ARDC Test Directive 5182-H1, Manned Balloon Flights, n.d.

53. Interview, Col. Stapp by Dr. Bushnell, 6 September 1957; R & D Project Card (DD Form 613), Biophysics of Escape, 14 May 1957, pp. 8-9, Lt. Romain C. Fruge, Jr., Chief, Balloon Sonde Unit, HADC, "Test Report on 'Manned Balloon Flights,'" May (?) 1953; Mr. Bernard D. Gildenberg, **Techniques Developed for Heavy Load Non-Extensible Balloon Flights** (HADC Technical Note 54-3), p. 10; Balloon Branch, HADC, **Test Report on The Manned Balloon Flight (7218)**, No. 1, 6 January 1956; **Test Report (Interim Status) on "The Threshold of Space,"** No. 1, 24 October 1955; interview, Capt. Joseph W. Kittinger, Jr., Escape Section, Biophysics Branch, Aero Medical Laboratory, WADC, by Dr. Bushnell, 9 June 1958; **Major Achievements in Space Biology at the Air Force Missile Development Center. . .1953-1957**, pp. 24-44.

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54. **Test Report on Project Whoosh,** Nos. 1 and 2 (combined) HADC, 1955.

55. Trip reports, Col. Stapp to Cmdr., 6580th Test Group, 25 May and 16 June 1954; interview, Project 7218 personnel, at WADC, by Dr. Bushnell, 6 November 1957.

56. Henry W. Wiant, **The Effects of Simultaneous Deceleration, Tumbling, and Windblast Encountered in Escape from Supersonic Aircraft** (WADC Technical Note 54-18, published March 1956), pp. iii, 4, 8, 27, 102, 107; Management Report (ARDC Form 111), Biophysics of Escape, 4 May 1956; ltr., Col. Stapp to Mr. Otto C. Winzen, subj.: [Project Whoosh], 13 January 1956; memo by Col. Stapp, subj.: [Coordination for Whoosh], March 1956; Stapp, "Human Tolerance to Deceleration," **American Journal of Surgery,** Vol. 93, p. 739 (in which Whoosh is discussed though not mentioned by name).

57. R & D Project Card, Biophysics of Escape, 14 May 1957, p. 12. For general data on the Hurricane Mesa Track, see "Telescoping Booms Stabilize Supersonic Ejection Seat," **ARDC Newsreview,** October 1957, p. 4.

58. John P. Stapp, **Human Requirements for Escape for High Performance Aircraft** (n.d.), p. 10; Missile Test Track Division, HADC, "Historical Data. . .1 April-30 June 1957," p. 4; interview, Capt. Mosely by Dr. Bushnell, 13 November 1957.

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64. Interview, Col. Stapp by Dr. Bushnell, July 1957.

65. Lt. Col. John P. Stapp, "Human Tolerance Factors in Supersonic Escape," **Journal of Aviation Medicine,** Vol. 28, p. 81 (February 1957). This article is Col. Stapp's contribution to the "Symposium" cited in footnote 61 and gives a general discussion of the relative merits of both capsules and ejection seats.

66. **Aviation Week,** 1 and 8 October 1956.

67. Lt. Col. John P. Stapp, **Escape from Aircraft** (n.d.), p. 3.

68. R & D Project Card (DD Form 613), Supersonic Ejection Seat (Project 2195), pp. 1-4; Neal, **Development of Methods for Escape; Aviation Week,** 7 April 1958. It should be emphasized that Lockheed and Convair are not in exclusive control of the industry-sponsored seat development but rather are "managers" of two distinct programs in which other companies participate.

V

Research Accomplishments in

BIODYNAMICS: DECELERATION AND IMPACT

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

1955 - 1958

1955 - 1958

In addition to major contributions in such space biology research fields as the hazards of cosmic radiation and the effects of subgravity and zero-g, the Aeromedical Field Laboratory of the Air Force Missile Development Center has made significant progress in biodynamics research. It was in 1953 that research in biodynamics began at the Holloman installation. As discussed in a previous monograph,[1] the initial primary concern in this area of endeavor was with the problem of escape from high-performance aircraft.

The memorable rocket-sled rides of Lieutenant Colonel (Doctor and later Colonel) John Paul Stapp were to provide data on human tolerance to windblast and deceleration encountered in escape situations. Research on the escape problem, however, has been only one aspect of the Laboratory's complex biodynamics program, and the famous high-speed track only one of the research and test facilities at Holloman Air Force Base that are used for this experimentation.

Tests conducted on the high-speed track, in addition to making available information related to escape, have provided pure research data on deceleration, and have also thrown light on such problems as aircraft crash forces and atmospheric re-entry. Furthermore, the Aeromedical Field Laboratory staff has developed certain specialized test instruments, ranging from a mere swing seat to the highly-instrumented 120-foot Daisy Track, for the study of a wide array of impact forces.

The biodynamics research program of the Aeromedical Field Laboratory has been conducted primarily under the auspices of Project 7850, which was established in 1954-1955 with the title Biodynamics of Human Factors in Aviation. However, aviation was never stressed to the exclusion of other problems. Even automotive crash research was conducted as a separate task of Project 7850, while other project activities were oriented toward problems of manned space flight. Indeed, with the post-Sputnik revolution in Air Force research activity, scientists of the Aeromedical Field Laboratory at last became free to emphasize space work to their hearts' content. It has now become the primary--though still not exclusive--interest of Project 7850, which in March 1958 was revised and renamed Biodynamics of Space Flight.[2]

From the standpoint of administrative organization, Project 7850 was originally entrusted to the Aeromedical Field Laboratory's Biodynamics Branch. When the laboratory received an important new mission in biosatellite work in mid-1958, the Biodynamics Branch went into a state of suspended animation, losing its chief, Captain (Doctor) John D. Mosely, and all its personnel to a new Satellite Operations Branch. The new branch also received responsibility for Project 7850, but with the understanding that it would receive low priority until people and resources were made available. Thus the biodynamics program, at least in the form known up to now, is also on semi-active status. But there is no intention of abandoning it outright. The program has already produced data that will be of value for a great many purposes, including biosatellite operations; and one other Air Force agency, the Aero Medical Laboratory at Wright Field, has promised to channel an ever growing amount of biodynamics work to the Holloman unit, especially in the testing of escape systems and personal equipment.[3]

Aircraft Crash Forces

One of the less exotic aspects of the biodynamics program--one which has received only a modest amount of research effort but which has yielded certain interesting results--has been that related to crash forces experienced in aircraft accidents. The study of aircraft crash forces has obviously much in common with the study of escape from aircraft. Moreover, the first aeromedical sled runs on the Holloman high-speed track to deal expressly with a topic other than escape from aircraft were concerned with aircraft crash forces. These runs began on 21 April 1955 and lasted through 28 June, overlapping slightly with the earliest of the high-speed windblast runs by the sled Sonic Wind Number 2.[4] Specifically, they aimed to reproduce the combined vertical and horizontal crash forces encountered in certain types of forced landings, basing the test configurations on actual crash data compiled by the National Advisory Committee for Aeronautics. As stated in one test report,[5]

Pilots of high angle of attack jet aircraft, such as the Delta Wing F-102, have incurred back fractures caused by forced landings in which the tail was dragging the ground at near stalling speed with the pilot seated in the nose 55 feet beyond the end of the tail, and 18 to 25 feet above the ground. When tail structures catch on ground obstructions, the nose of the aircraft can be slammed to the ground viciously with forces estimated at better than 60 g's. For the protection of pilots, it is necessary to evaluate the combined effect of the two components by reproducing them on the deceleration sled.

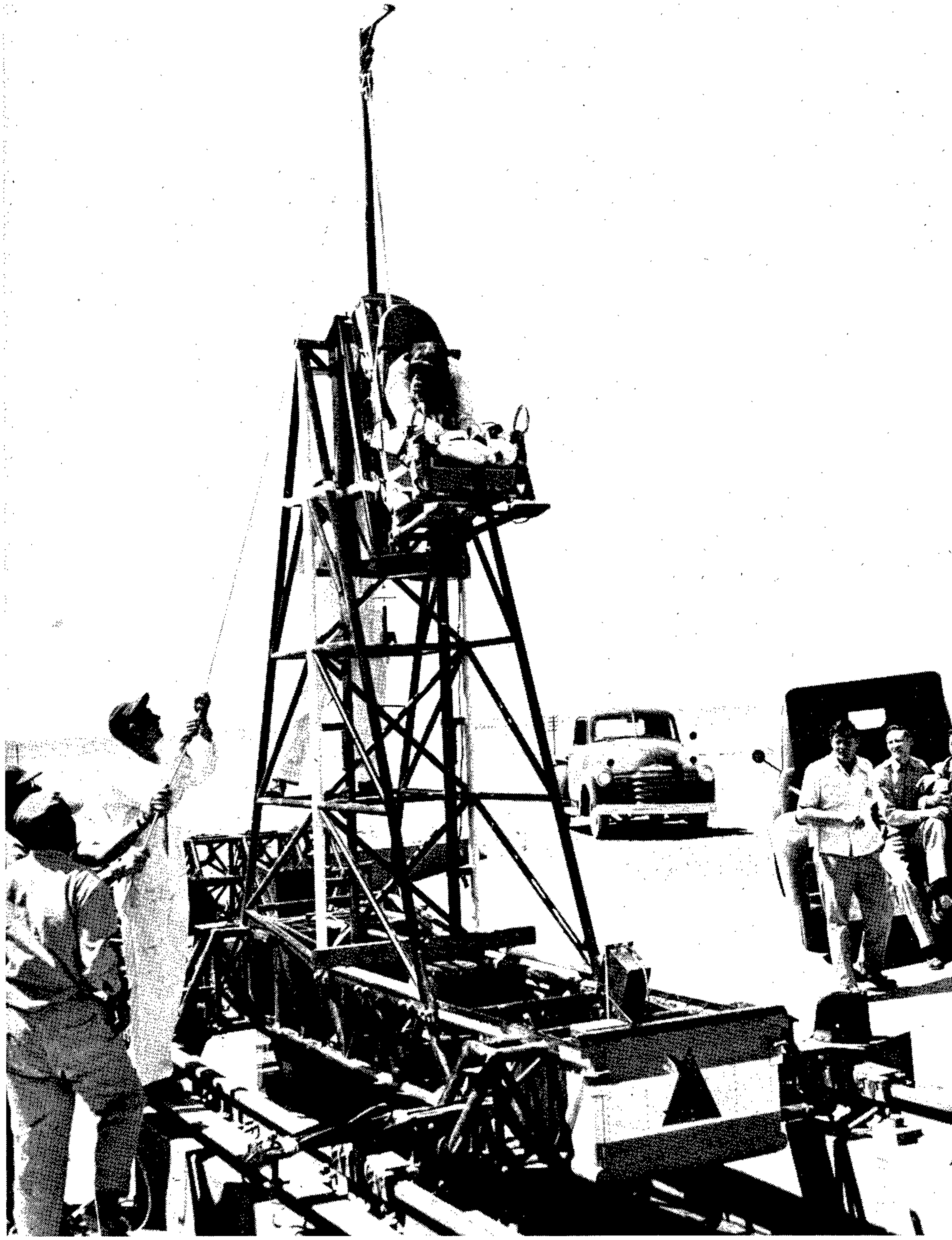
In these tests, an F-102 seat was rigged to drop vertically seventy inches and decelerate by impinging on a metal cylinder, while at the same time the entire apparatus, attached to a rocket sled, was being decelerated horizontally by water brakes on the high-speed track. In the first full-scale experiment of 21 April--which followed a series of static tests--an anthropomorphic dummy was used, sustaining peaks of roughly fifty g's vertical and twenty-five g's horizontal deceleration. Subsequently, anesthetized chimpanzees took part in the experiments. With varying types of protection and no irreversible injury, they received forces ranging up to sixty g's vertical in combination with twenty g's horizontal deceleration. Taken as a whole, the experiments supplied valuable data both on crash forces as such and on the value of different crash restraints and energy-absorbing seat cushions. For example, they demonstrated how the impact of vertical g-forces could be reduced by means of up-lifting chest and shoulder straps.[6]

Aircraft crash forces have also been studied on the crash-restraint demonstrator, informally referred to as Bopper, which is one of the specialized test facilities established at Holloman solely or primarily for the work of the Aeromedical Field Laboratory. The original version of the Bopper was acquired from Northrop Aircraft, Incorporated in March 1955 and was replaced by an improved model a year later. It is a seat propelled by elastic shock cord along a short, portable stretch of track; it can impart g-forces of short duration, with magnitude (on the new model) up to about thirty g's.

The Bopper was used in a special study of subject responses to low-impact aircraft crash forces. Participants in this test series experienced deceleration on the Bopper ranging up to twelve g's in aft- and forward-facing positions, secured with seat belt only. Immediately after exposure, each subject released the seat belt manually and proceeded along an aisle to a simulated emergency exit. Subjects were carefully observed to see how quickly and efficiently they were able to release the belt and reach the exit--something that must be executed without delay whenever there is danger of flash fires breaking out or in the event of a water landing. The results indicated that responses were slightly better after deceleration in the backward-seated position, thus supporting a point of view that Colonel Stapp and many other aeromedical officers had often urged upon the aviation industry, without much success.[7]

Although a technical note published on these Bopper tests related them expressly to an aircraft crash problem, any data on g-tolerances with seat-belt restraint was also of interest for automotive crash research. The officer who directed these tests (together with Colonel Stapp, who was chief of the entire laboratory from April 1953 to April 1958) was Lieutenant Sidney T. Lewis, whose primary assignment was task scientist for Automotive Crash Forces (Task 78507 of Project 7850). Naturally, much of the work performed under the automotive crash program was applicable in turn to aircraft crash studies. Similarly, tests have been performed on the Daisy Track, whose main purpose is basic research on impact forces, in order to evaluate particular types of aircraft crash harness. Both the automotive crash program and the operation of the Daisy Track will be discussed below in greater detail.

However, at no time since the F-102 drop-seat experiments has aircraft crash research, as such, been one of the major activities of the Aeromedical Field Laboratory. When Project 7850, Biodynamics of Human Factors in Aviation, was established, it contained a separate Task 78506, entitled Tolerance to Aircraft Crash Forces; and there was even talk of staging barrier crashes with jet aircraft on the Holloman high-speed track. But no such experiments were held, nor did the aircraft crash program ever have a full-time task scientist. In March 1958, finally, when Project 7850 was revised to become Biodynamics of Space Flight, Task 78506 was changed from Aircraft Crash Forces to Patterns of Deceleration in Space Flight.



Drop Seat Used in Aircraft Crash Experiments on the High-Speed Track

The new version of this task will also be discussed more fully below. Even now, aircraft crash study will not necessarily be excluded altogether from the work of Project 7850. Project documentation indicated that research would be conducted on "dynamic stress characteristics of the human body" as a factor in "design and specifications" for both aircraft and space vehicles; and the project is still interested in "impacts," which in turn include crash forces.[8]

Later Deceleration Studies on the High-Speed Track

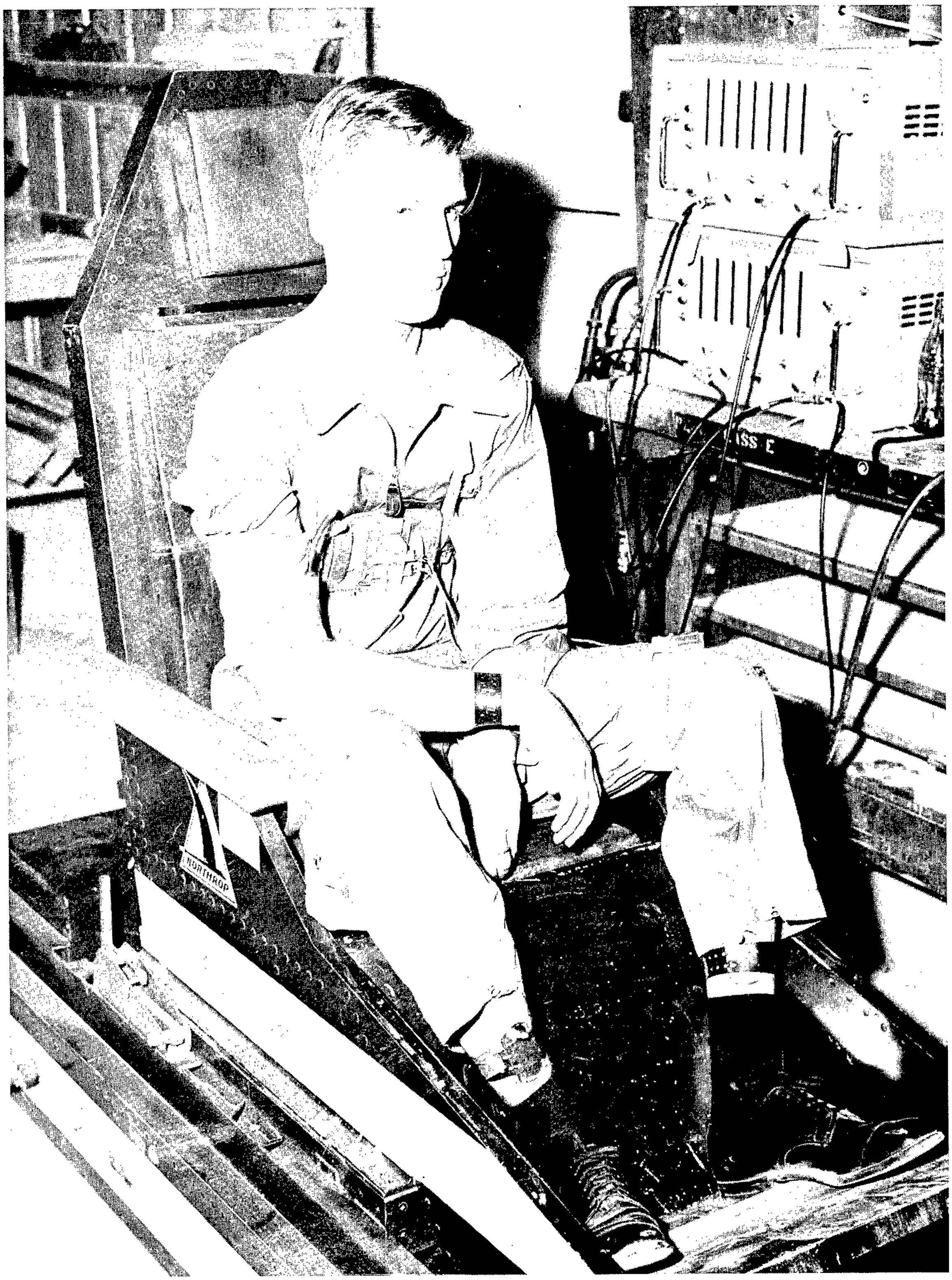
A separate monograph described how research at Holloman on escape from aircraft (as distinct from aircraft crash forces) led to high-speed track studies of windblast and deceleration that reached an early climax in Colonel Stapp's sled ride of 10 December 1954. That experiment was followed by further research studies with chimpanzee subjects on the high-speed track, but later experiments followed two increasingly divergent paths, one concerned with windblast **per se** (as described in the previous study) and one with high-g, horizontal deceleration. The tests designed expressly for deceleration finally attained such high g-forces that windblast effects, if any, were wholly overshadowed. There also came a point, impossible to specify exactly, where g-forces produced were so much greater than even the momentary peaks likely to occur in an escape situation that such tests were no longer directly relevant to the aircraft escape problem. The fact that the tests went right ahead reflects a continuing interest in basic research data on deceleration, whether or not an immediate practical application was apparent.[9]

Colonel Stapp, on 10 December 1954, experienced a g-plateau of twenty-five g's and peak force of forty g's. By November 1955, chimpanzees were being exposed to as much as eighty g's programmed deceleration at 4860 g's per second rate of onset. A final series of fifteen high-g experiments was held from October 1956 through March 1957, just after the track itself had been extended from 3550 to 5000 feet. Greater velocities and substantially higher g-forces now became possible even with the relatively heavy deceleration sled Sonic Wind Number 1. Programmed deceleration in this test series ranged up to 120 g's, but peak forces went considerably higher. A force of 247 g's was produced on one subject for a millisecond on 2 February 1957. Rate of onset for that same test was 16,800 g's per second, which was also a record; and total duration of the decelerative phase was 0.34 second.

The effect on chimpanzee subjects naturally varied with the number of g's, duration, and also body position. The run of 2 February 1957 that attained a peak of 247 g's caused only "moderate" injuries to the test subject, but this happened to be the one run in the series in which the chimpanzee was seated facing backward. A run of 12 January 1957, with the subject facing forward, proved fatal even though the peak force was only 233 g's for one millisecond (total duration .35 second) and rate of onset slightly over 11,000 g's per second. One other fatality occurred at considerably lower deceleration, but in this case the subject's death was apparently due in large part to an ailment unrelated to g-forces. Speaking of the entire series of high-g runs on the 5000-foot track, Colonel Stapp later observed that "significant" injuries began in the neighborhood of 135 g's--with extremely short exposure, and with the subject enjoying the benefit of "maximum restraint." He also hypothesized that in the two standard seated positions, backward- and forward-facing, chimpanzee tolerance to transverse g was roughly comparable to that of human beings; but this is a subject of some controversy, and admittedly, when it came to probing the range of severe to lethal injury, no human test subject would attempt to verify the assumption.[10]

The later deceleration experiments were undertaken essentially as a form of basic physiological research, but the test results have been cited--by Colonel Stapp among others[11]--in connection with such problems of space flight as takeoff and re-entry of manned space vehicles. To be sure, rocket acceleration at takeoff will involve moderately high g-loads, which are generally regarded as tolerable on the basis of centrifuge tests and actual rocket experiments with animal subjects. Total durations would be longer than in the high-speed track deceleration tests, but it is predicted that peak g-forces will be on the order of eight to twelve g's.[12]

In the case of re-entry, a vehicle coming back from extreme altitude or outer space must encounter high decelerative forces as it comes in contact with denser layers of air. Such deceleration poses a complex problem for potential travelers, whether human space crews or animal test



Captain John A. Recht Seated on "Bopper"

subjects, and two basic solutions have been suggested: to come straight down, experiencing high g-forces but holding them to short duration, or to follow a gradually descending path, with moderate g-forces but long duration. Other possible solutions lie in between. In any case, scientists concerned with the re-entry problem wanted a mass of data on tolerance to deceleration, including data on the forces that would be required to produce serious biological injury; and the tests on the Holloman high-speed track helped supply the information needed.

No one expects that re-entry configurations will call for exposure to forces even approaching the extreme decelerations applied in some of the Holloman tests. On the other hand, re-entry patterns are more problematical than the accelerations anticipated in manned space travel. A year and a half ago, before the various Soviet and United States satellites contributed new knowledge on the density of the upper atmosphere, re-entry patterns were even more problematical than they are now. In reaching conclusions about human tolerance from chimpanzee test results, moreover, it is desirable to have a wide margin for possible error. At the very least, whether for re-entry or for other operational problems, it is comforting to know that fellow primates have experienced forces above one hundred g's with only minor injury, and in one case actually lived through a deceleration of almost 250 g's.

Other Research Related to G-Forces Anticipated in Space Flight

Track-testing could not, of course, provide all the data needed to study the g-patterns of future space flight. It could produce extremely high g-forces but was limited to short durations. For more prolonged exposures, it is necessary to turn to centrifuge testing, and especially to the human centrifuges located at the Aero Medical Laboratory of Wright Air Development Center and at the Aviation Medical Acceleration Laboratory of the Naval Air Development Center, Johnsville, Pennsylvania. The Johnsville centrifuge, in particular, was used for one series of tests oriented toward the re-entry problem in which Holloman's Aeromedical Field Laboratory also participated.

During the winter and spring of 1956-1957, the Human Factors Division (later Directorate of Life Sciences) of Headquarters, Air Research and Development Command arranged this test series as an interservice research effort in which the Aeromedical Field Laboratory supplied chimpanzees, the Navy's Johnsville centrifuge spun them at high g, and the Armed Forces Institute of Pathology performed autopsy services. Colonel Stapp helped coordinate all these efforts, and Captain John D. Mosely, who headed the Aeromedical Field Laboratory's Biodynamics Branch, assisted the Navy at Johnsville in the actual centrifuge runs.

Several different tests were made, subjecting chimpanzees to as much as forty g's applied transversely for sixty seconds. The test configurations were dictated primarily by re-entry planners, who allowed a wide margin for possible differences between chimpanzee and human tolerances. All five chimpanzees used survived the centrifugation, but electrocardiograph abnormalities were recorded during the tests, and internal injuries were found when the animals were sacrificed afterward. The one animal that took forty g's for sixty seconds in a completely supine position was apparently little harmed by the experiment; the same could not be said of the other four, which were tested in partially prone or partially supine position and suffered more severe damage. Just what this proved for re-entry was not wholly clear, in view of the uncertain correlation between chimpanzee and human tolerances. However, the test results did confirm the dangers involved in exposure to prolonged high g.[13]

The Aeromedical Field Laboratory proposes to conduct further experiments of its own on the g-forces anticipated in manned space travel as a part of Task 78506 (of Project 7850), Patterns of Deceleration in Space Flight. As already mentioned, this task was established in place of the former Task 78506, Tolerance to Aircraft Crash Forces, at the same time that Project 7850 was rewritten as Biodynamics of Space Flight. Task Scientist since the beginning has been Lieutenant Albert Zaborowski, although he has never been able to devote all his time to this one activity.

Despite the formal title Patterns of Deceleration in Space Flight, the task program is concerned with acceleration as well as deceleration problems. Principally, it

aims to simulate the following conditions of space flight with both animal and human subjects:[14]

1. The "notched" decelerations encountered during multi-stage rocket takeoff, with varying periods of coasting between the three thrust stages.

2. The forces encountered during maneuvering of the space vehicle at extremely high velocities using reverse or unbalanced rocket thrust.

3. The forces encountered on impact during landings on other planets.

4. The forces encountered during re-entry into the atmosphere.

The Holloman complex of test facilities offers many possibilities for experimentation along these lines. The recent extension of the high-speed track to 35,000 feet naturally increases the range of possible test performance with that instrument. Task 78506 may also use the short Daisy Track for some purposes, and has already used the Bopper or crash-restraint demonstrator for deceleration experiments in which the "test subjects" were blocks of wood immersed in sugar solution.[15]

As indicated by this last type of experimentation, the Aeromedical Field Laboratory is one of the various research agencies currently interested in the use of fluids for g-protection. Journalists and information officers have taken delight in tracing the theoretical principles involved in this all the way back to ancient Greece, and in giving credit to Archimedes as the spiritual father of underwater g-protection.[16] The starting point for modern research in this field appears to be a German effort in the 1930's to develop water-lined anti-g suits. Even better known are Canadian tests during World War II in which the subject was spun on a centrifuge with most of the body under water. The Canadians were looking for ways to improve their aircraft anti-g suits, and they decided at the time (as the Germans had earlier) that water protection was not wholly practical for this purpose.[17]

Since 1957, the United States Navy's Aviation Medical Acceleration Laboratory and the Aero Medical Laboratory at Wright Field have been conducting human centrifuge tests on the water-immersion principle. So far, the Navy holds the record as to maximum g-forces sustained with the aid of water immersion: four seconds above fifteen g's, with a peak of sixteen. This is part of one simulated re-entry pattern, and indications are that "considerably" higher tolerance levels can be attained in future experiments. But the Wright Field scientists, whose present equipment sets a limit of about twelve g's for this type of testing, hold the record as to durations. Tolerance has been established at twelve g's for almost four minutes.[18]

From human experiments it is a far cry to Lieutenant Zaborowski's wooden blocks. Obviously, his Bopper tests were only to explore test procedures, including the effects of using different solutions. Later tests will be made with fish, frogs, and small mammals; in fact, another activity in which Lieutenant Zaborowski has been engaged is the design and fabrication of a special mouse diving suit. The culmination of this one type of research will be tests on the 35,000-foot track with chimpanzee or human subjects submerged in a special water tank that is already on order. It should not be thought, however, that Task 78506 is exclusively concerned with the possible uses of fluids in manned space flight. It merely happens that the first actual experimentation was directly related to this procedure. In the end, a wide range of g-patterns will be tested both with and without this and other protective devices.[19]

Although research on acceleration and deceleration patterns of space flight was primarily a responsibility of the Biodynamics Branch, at least until the recent reorganization of the Aeromedical Field Laboratory, staff members of the Space Biology Branch--which has been abolished outright--made some contribution to these studies. The Space Biology Branch, headed by Lieutenant Colonel (Doctor) David G. Simons, had charge of Project 7851, Human Factors of Space Flight, which took in both subgravity research and the various cosmic radiation and cabin environment studies that gave rise to the Man-High balloon flights. However, Project 7851 also contained a separate Task 78502, entitled Descent and Recovery (Re-entry).

When first established in 1954, this task was regarded as a natural outgrowth and continuation of work done earlier in devising techniques for the recovery of animal capsules carried to the upper limits of the atmosphere in research rockets. Simons personally had been concerned with "descent and recovery" of the first two

biological V-2 experiments in 1948-1949, when, as an officer of the Aero Medical Laboratory at Wright Field, he helped launch these flights from White Sands Proving Ground, New Mexico. Some of his experience in recovery of balloon-borne animal experiments for cosmic ray research was likewise valuable for the task program. As it developed, however, the task also looked ahead from recovery of animal experiments toward an examination of deceleration, thermal effects, and related problems posed by re-entry of manned vehicles into the earth's atmosphere.[20]

For lack of sufficient people and resources, Descent and Recovery (Re-entry) as a separate task was never fully activated. One of several part-time task scientists who worked on the program at different periods was Mr. Reinhard Krause, an aeronautical engineer whose primary assignment was to another unit of the Air Force Missile Development Center's Directorate of Research and Development (now Directorate of Advanced Technology). Krause did not attempt to conduct a test program but contributed some theoretical calculations concerning velocities and decelerative force in possible re-entry trajectories. (Subsequently he published a technical report, co-authored with W. F. Haldeman, entitled **Vertical Descent Trajectories Including Re-entry into the Atmosphere.**) The most recent task scientist was Captain Druey P. Parks, who also served as administrative officer of the Space Biology Branch, but he inherited this role at a time when he was chiefly engrossed in preparations for the Man-High program of high-altitude balloon flights and thus unable to devote much attention to Task 78502.[21]

Part of the effort spent on Man-High was at least related to Task 78502. Various scientific experiments were planned in connection with the Man-High flights in order to accumulate data on physical conditions of the upper atmosphere. These naturally had some bearing, directly or indirectly, on such problems as re-entry, one example being the attempt (which proved unsuccessful) to measure gravity at high altitude with a balloon-borne gravity meter.[22] Then, in the lull that followed Simons' record ascent of 19-20 August 1957, Captain Parks was able to devote his main efforts at least briefly to the work of Task 78502. He began modestly, proposing to drop anthropomorphic dummies from high-altitude balloons in an open escape device, either the experimental Convair "B" ejection seat with rounded bottom and stabilizing booms or the intermediate Weber F-106 seat. After a number of balloon bursts and weather difficulties, the first wholly successful test took place on 29 January 1958, when the Convair seat was dropped from 85,000 feet and accelerated by free fall in 37.12 seconds to a maximum speed of .98 mach, at which point it began to slow down from air resistance. G-forces, oscillations, and other free-fall characteristics were studied in this carefully-instrumented introductory experiment. According to project plans, tests were to be staged later on with high-velocity rocket test vehicles, in order to simulate and study different re-entry curves.[23]

These later tests have not and will not be conducted, since shortly after the 29 January experiment the task itself was formally eliminated from the Aeromedical Field Laboratory program. This move was taken chiefly on grounds of duplication of research at Wright Air Development Center, which had primary responsibility for re-entry work in the United States Air Force.[24] The Holloman laboratory will nevertheless continue to contribute pertinent data on re-entry decelerations through its over-all program in biodynamics.

Another scientist who was assigned until recently to the Space Biology Branch, Dr. Harald J. von Beckh, has been working intermittently on a device of his own for protection against g-forces. Von Beckh came to Holloman as task scientist for subgravity studies, and within the general field of subgravity research he was especially interested in the effect of weightlessness immediately preceded or followed by relatively high g-forces, as in rocket takeoff and re-entry. His experimentation along these lines has been discussed in another monograph of this series.[25] At the same time, however, he has conceived an "anti-g capsule" which could give protection not by water immersion but by automatically positioning the body at all times to receive g-forces transversely, in which case human tolerance levels are invariably highest. Dr. von Beckh has proposed that this system be used in developing a capsule for escape from aircraft, but it is also applicable for use in space vehicles.[26]

Von Beckh has already tested the basic features of his idea in animal experiments at Holloman. In the early part of 1958, he exposed mice to high g-forces on two small materiel centrifuges and established that their tolerance was substantially increased by attaching them to a swinging anti-g platform of his own making. Accelerative stress in a direction longitu-

dinal to the body was negligible, since the platform automatically positioned the mice to receive their g's transversely. Though dizzy from spinning at the end of the run, the mice survived exposure to 400 g's for almost fifteen seconds.[27]

A slightly different form of Dr. von Beckh's device has produced similar results (though at much lower g-levels) with rats on the short Daisy Track,[28] which is discussed in the following section of this monograph. Still another variation has even been used operationally, in rocket experiments with animal subjects. This was a purpose for which Von Beckh predicted that his device would prove extremely helpful, since[29]

> . . .during the re-entry phase, during ejection from the nose cone and especially during uncontrolled parts of the trajectory, which might be caused by imperfections of the automatic guidance system, the subject would be exposed to severe accelerations with continuously varying direction, intensity, and rate of onset.

Accordingly, Dr. von Beckh's principle was frankly copied in the experiment that sent three ill-fated mice aloft in three Thor-Able missiles from the Air Force Missile Test Center, Florida, in the course of 1958. Two of Von Beckh's Holloman colleagues, Captain (Doctor) Grover J. D. Schock and Technical Sergeant Edward C. Dittmer, were even present at the Ramo-Wooldridge Corporation in Los Angeles, helping project scientists to incorporate the anti-g device as well as giving advice on environmental control problems for the Thor-Able mouse compartment.[30] Alas, all the mice were lost at sea, so that there is no way of knowing how well the anti-g device functioned in this case.

Tolerance to Impact Forces (Task 78503): Research on the Daisy Track and Related Test Facilities

Probably the most active of all the formal subdivisions of Project 7850 has been Task 78503, Tolerance to Impact Forces. Other tasks of the same project are concerned with impact forces, but usually with application to a particular set of operational problems. Task 78503, by contrast, seeks to compile basic research data on as broad as possible a range of short-duration g-forces.

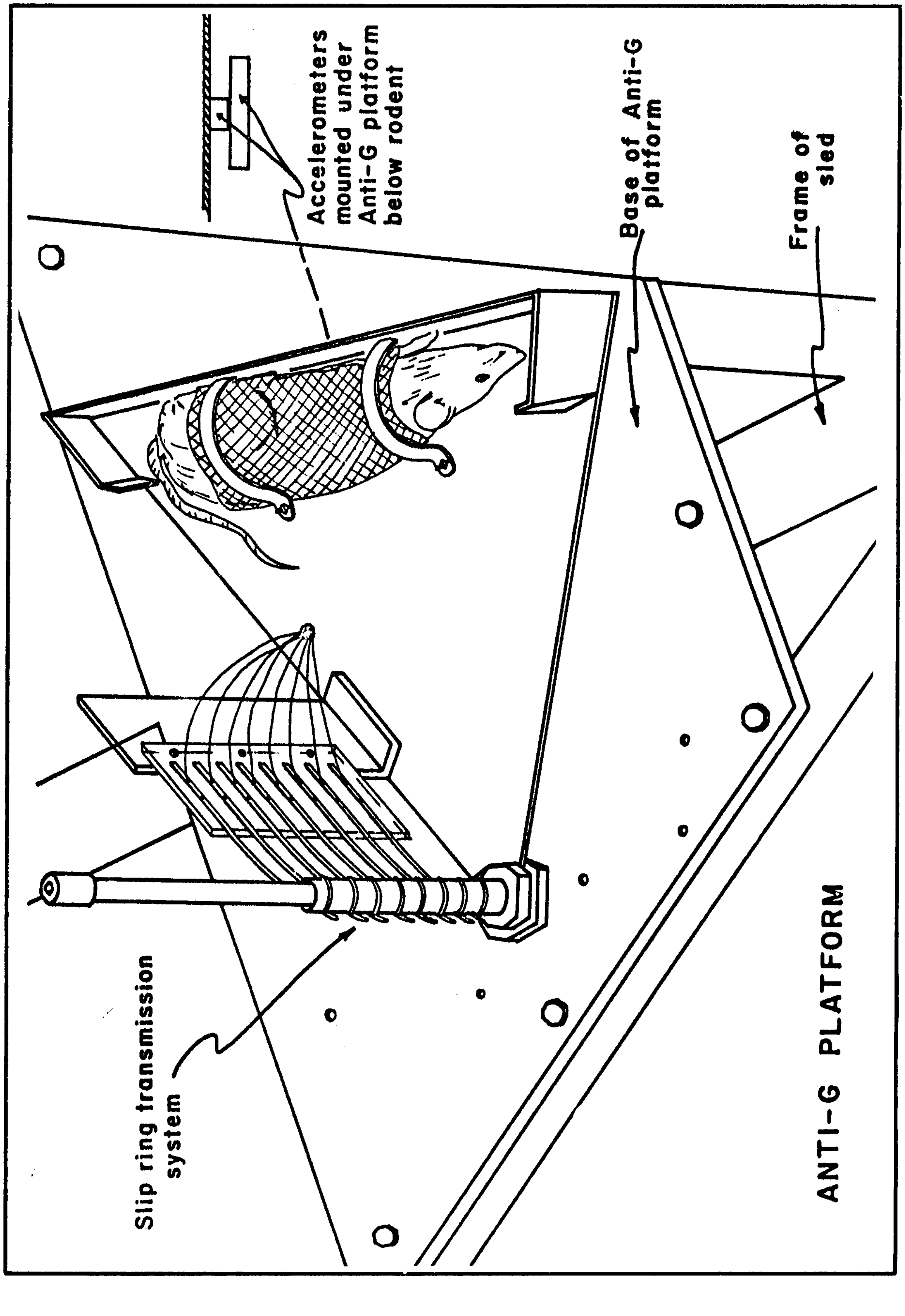
The task objective has been stated as follows:[31]

> Human, animal, and anthropomorphic dummy reactions to dynamic linear forces of 50 to 5000 g per second rate of onset, 10 to 200 g magnitude and durations of 10 to 100 milliseconds will be determined for all phases of body orientation.

Not all official statements have used these same figures, which are intended only to provide a rough frame of reference, and most of the high-speed track deceleration experiments fell within the limits set. However, those experiments were conducted as a "project-level" activity and were not looked upon as coming under any one task subdivision. The primary, though not the only, instrument for the research of Task 78503 has been the Holloman short track, or Daisy Track as it is usually called.

The Daisy Track was designed expressly for use by the Aeromedical Field Laboratory, was formally inaugurated in 1955, and is located immediately adjacent to the buildings of the laboratory complex. It consists of two rails five feet apart and 120 feet long. According to the original proposal made in 1953 by Colonel Stapp, who was then head of the laboratory, propulsion was to have been by compressed air catapult--hence the analogy with the popular Daisy air rifle which gave the track its name. As a result of administrative and funding complications, this propulsion device still is not in service, although it is currently on order and parts of the equipment have been delivered. In the meantime, propulsion is by powder-cartridge catapult. This system has been reasonably satisfactory even though it cannot offer quite the same precision or performance range.

Braking for deceleration was provided at first by a lead cone device, but this proved unsatisfactory in preliminary tests. A water braking system was then adopted instead and is still in use. The original sled used on the Daisy Track required the subject to lie on his side in a "seat" that could be rotated in all directions by fifteen-degree increments; in high-speed track sled experiments, by contrast, the subject had to assume one of two positions, forward- or backward-facing in an upright seat. Moreover, in the autumn of 1957 the Aeromedical Field Laboratory acquired another sled with upright seat suitable for use on



ANTI-G PLATFORM

the Daisy Track. Orientation of this seat can be changed by ten-degree increments through a full 360 degrees.[32]

The one area of performance in which the Daisy Track simply cannot compete with the long track is sled velocity and thereby exposure to windblast. In deceleration, it is capable of producing g-forces as high as those that have been obtained in aeromedical tests on the long track, although it does not provide as long an exposure to decelerative force. The number of possible body orientations was a distinct advantage, and since the operation of the Daisy Track required less elaborate preparations, a greater number of experiments could be run in the same period of time. The Daisy Track provided more accurate and abundant measurements by means of "direct recording pickups with trailing cable leads" from the sled to a fifty-channel oscillograph. Last but not least, the Daisy Track was remarkably inexpensive to operate. Runs cost about one hundred or one hundred fifty dollars each, as against the usual several thousand dollars for a test on the high-speed rocket track.[33]

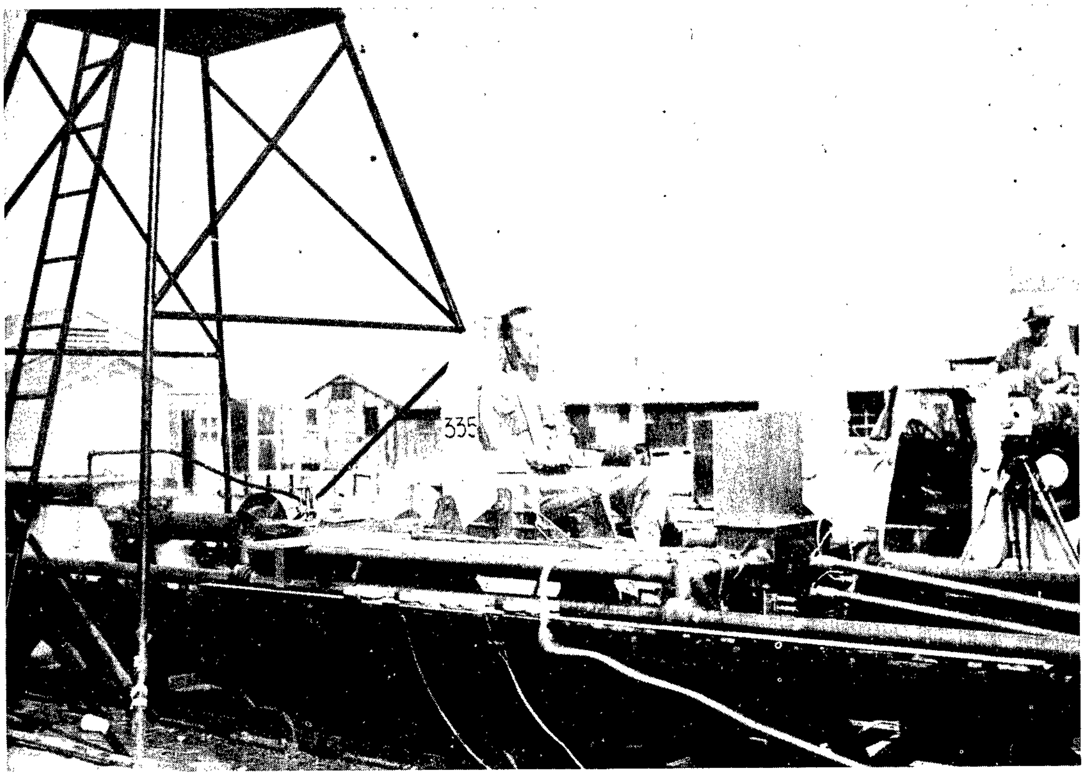
The Daisy Track was completed in the summer of 1955, and the first actual sled run took place on 22 September 1955. This was only a preliminary test, and it was several weeks before a run was made with a live subject. There were various adjustments to be made first on the basis of preliminary testing, including replacement of the unsatisfactory lead cone braking device. The first chimpanzee subject tried out the new facility in mid-November; still more animal runs and engineering testing experiments, not to mention two dummy runs, were then held before the first human experiment on 17 February 1956. The original volunteer subject was Lieutenant Wilbur C. Blount, who at that time was task scientist for Task 78503.[34]

The Daisy Track has remained one of the busiest of Holloman's specialized research facilities, despite some temporary interruptions. One such interruption occurred early in 1957 when the Center's Missile Test Track Division (now called Track Test Division), which has ultimate supervision over both long and short tracks, expressed fear that the one sled then available was unsafe as a result of the heavy loads it had sustained. The sled was taken out of commission for about a month while undergoing x-ray studies, and when these revealed no sign of cracks or metal fatigue the facility went back in operation. In September of the same year, the number of Daisy runs accomplished passed the two hundred mark, and by mid-October 1958 it stood at 390--as compared with less than a hundred aeromedical experiments on the long track from November 1953 to the present.[35]

Animal experiments have figured less prominently in Daisy tests than on the long track. Most test configurations to date have not been of an order to cause serious injury, and therefore it has normally been possible to use human subjects. Nevertheless, chimpanzees did take part in some of the early tests and helped check out the facility for human use. On two later occasions, hogs, which have never been privileged to ride the long track, took part in preliminary experiments with a new test configuration and received spinal fractures from an impact force measured at less than thirty g's. This unfortunate result was due to the particular combination selected of g-forces and body orientation (forces parallel to spine), and to the nature of the hogs themselves, including the "virtual impossibility of properly restraining these animals" on the sled.[36]

Bears, which joined the Aeromedical Field Laboratory staff only in the fall of 1957, have also ridden the Daisy Track. The first instance occurred in connection with an automotive crash conference described below, but soon afterward runs were started in a test series "seeking correlation between spinal injury in bears and humans." Finally, rats served as subjects in tests of Doctor von Beckh's anti-g swinging platform on the Daisy Track. Runs have not been made expressly for the rats, but the anti-g platform is small enough to be mounted on the sled in tests scheduled primarily for some other research objective. It has been notably successful so far, increasing subject tolerance by holding longitudinal g-forces (as distinct from transverse) to insignificant values even on some relatively high-g runs.[37]

Human tests, which have formed much the greatest part of research activity on the Daisy Track, started out with a series of low-g experiments mainly intended for subject indoctrination. Since then, most officers and enlisted men assigned to the Biodynamics Branch have taken part as subjects, naturally including Captain Eli L. Beeding, Jr., who succeeded Lieutenant Blount as task scientist in the latter part of 1956. Colonel Stapp likewise took part, although his three Daisy rides failed to attract the same attention as his earlier rides on the long track. His so-called "grounding" from high-speed track experiments in June 1956 did not, of course, apply to Daisy tests.



16 May 1958: Captain Beeding Absorbs 83 G's on the Daisy Track
(Below: Close-up of the Same)

Test subjects on the Daisy Track have tolerated forces above thirty g's in the relatively unfavorable position that is standard for upward ejection from aircraft (g-forces parallel to spine). Still higher forces have been sustained without injury in other body positions. Total durations have been as low as .035 second and have seldom much exceeded one-tenth second--as compared with a plateau of more than twenty-five g's for 1.1 seconds recorded on Colonel Stapp's rocket sled ride of 10 December 1954. Physiological effects have varied with maximum force, duration, body position and restraints, and also individual tolerance, which is much higher for some persons than for others. But no test has ever produced more than temporary ill effects.[38]

The all-time record among Daisy tests was a run of 16 May 1958, with Captain Beeding himself as test subject. Deceleration measured on Captain Beeding's chest was eighty-three g's, substantially more than the highest g-force previously experienced in any human experiment either at Holloman or at other research installations. Duration was one-tenth second and rate of onset calculated at 5000 g's per second; position was seated upright and backward-facing. After the run Captain Beeding gradually went into a state of shock, but he recovered in less than ten minutes. He entered the base hospital for treatment of sore vertebrae and detailed observation, but apparently suffered no permanent ill effects. On the other hand, Captain Beeding admitted that he considered eighty-three g's about the limit of voluntary human tolerance for the test configuration that was used. He pointed out further that his experience underscored the desirability of backward-facing seats in passenger aircraft; there is even some question whether he would have lived through the ordeal if his seat had been facing the other direction. It is interesting to note, finally, that Captain Beeding did not ride alone on 16 May 1958. His sled also carried Doctor von Beckh's anti-g platform, whose rat passenger did not go into a state of shock.[39]

Since the aim of Task 78503 is to accumulate general research data on the physiological effects of impact force, test configurations on the Daisy Track are not necessarily determined by any one specific Air Force problem. However, the track has also been used to test particular items of equipment, such as integrated harness designs for B-52 and F-104 aircraft, and force-attenuating seat cushions. It has even been used to check out recording equipment for the Holloman high-speed test track. In the case of B-52 harness testing, runs had to be suspended before completion of the planned series because one test at thirty-five-g level caused hospitalization of the subject for two days. Arrangements were then made to have the harness equipment redesigned.[40]

For that matter, data acquired on impact forces **per se** will be useful for study of a great many different problems. These include not only aircraft seating arrangements, but also stresses in catapult and rocket takeoff, and re-entry deceleration. Something has been said in a previous monograph concerning the importance of research on the Daisy Track for study of escape from aircraft. Even so, it is worth noting again here as one example that the tests in which men sustained over thirty g's in position for upward ejection and emerged unharmed appear to give more leeway--or at least a greater safety margin--to the designers of escape systems than was formerly thought possible.[41]

As stated before, the Daisy Track is the primary but not the only research tool for Task 78503. The Bopper, described in connection with aircraft crash experiments, is a fairly handy instrument for general study of impact forces as well, although naturally it is an instrument of much more limited performance than the Daisy Track. Still another device for study of impact forces is a swing seat prepared in mid-1955 especially for aeromedical research and located, like the Daisy Track, in the back yard of the Aeromedical Field Laboratory. The swing has a platform on which an aircraft or other type seat is installed, raised to desired dropping height by means of a crane, and then decelerated by aircraft cables attached to the back of the platform at the moment its fall places it perpendicular to the ground. Forces are applied for extremely brief duration--for example, twenty-three g's with the peak lasting just one millisecond. The swing seat is capable of greater g-forces than this, depending principally on the height from which the seat is dropped; but it has various limitations, and to some extent it has served simply to obtain rough parameters for the planning of other experiments. It has also been used in its own right for certain test series relating principally to Task 78507, Automotive Crash Forces, and it will be discussed further under that heading.[42]

In June 1955, even before the inauguration of the swing seat, a more primitive variety of impact test was conducted

Swing Seat with
a. Three-Inch-Wide Lap Belt
b. Snub Cable Decelerator

in which a shot bag was simply dropped against an anesthetized hog "to determine the threshold of tissue damage by force transmissible through the abdomen wall . . . ." This was an area of the body especially vulnerable to crash forces, so that the test procedure was of obvious interest for both aircraft and automotive crash research. The officer directly in charge of the shot-bag experimentation--Major Joseph V. Michalski, who technically preceded both Lieutenant Blount and Captain Beeding as task scientist of Task 78503--managed to conduct just one actual test before leaving Holloman in mid-1955 on permanent change of station. However, this was a forerunner of other impact tests with hog subjects on the swing seat that were held specifically under the auspices of the automotive crash program.[43]

One final example of the concern of the laboratory's biodynamics program with all manner of impact forces is the effort spent on developing a nonpenetrating projectile which can be fired at close range "to produce concussion in animal subjects."[44] This effort was technically considered a part of Task 78503, but was assigned as a part-time additional duty to Captain (Doctor) John A. Recht, a trained veterinarian whose primary responsibility is to care for the Holloman laboratory's animal colony. Recht tested various types of rounds before finding one that seemed workable for research purposes. Because of limited time and resources, no serious testing has been conducted with this device, but potentially it could make a contribution not only to basic research on concussion but also to the study of specific crash problems such as the effect of collision with loose objects in an aircraft cockpit.[45]

Tolerance to Total Pressure Change: Task 78504

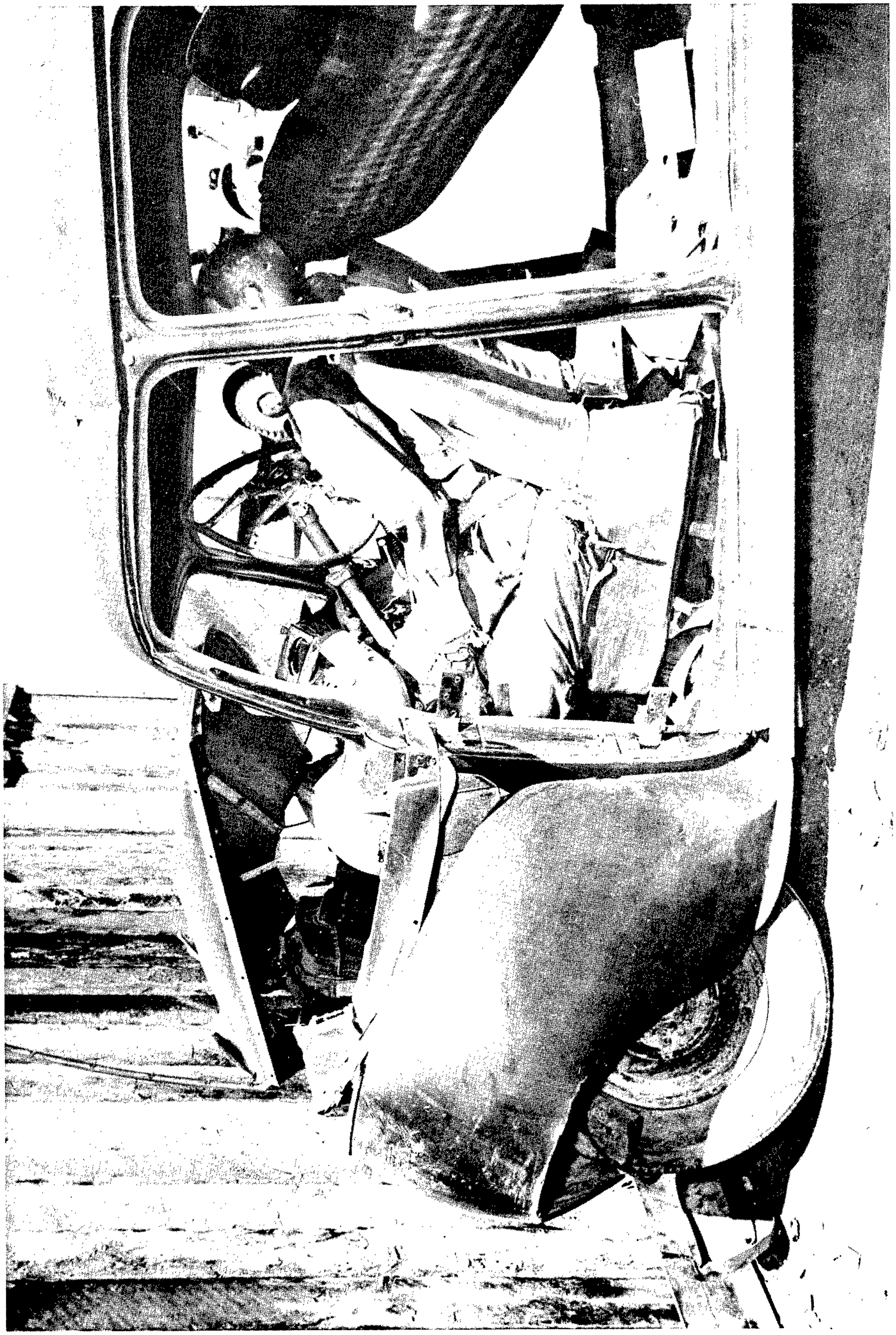
Another task of Project 7850 is Tolerance to Total Pressure Change (Task 78504), which seeks to determine human and animal responses to negative or positive total pressure change in the range of one to ten atmospheres occurring in .005 to five seconds and in single or multiple cycles.[46] Task scientist from 1956 until he left the service in mid-1958 was Captain (Doctor) Donald F. Patterson, an Air Force veterinarian who like Captain Recht was assigned to the Veterinary Services Section of the Aeromedical Field Laboratory's Laboratory Services Branch (now Laboratory Branch). At present the task scientist is Lieutenant William Ward.

In explaining the objectives of this task, Captain Patterson pointed out that the physiological effects of[47]

> . . .increased pressures on the human body surface have been studied in relation to undersea diving, but investigations in this area have been largely concerned with slowly increasing pressures such as are encountered in descent beneath water. The effects of abruptly increasing, or rapidly cycling pressures as are exerted on the body due to windblast and deceleration during high speed bailout have not been adequately studied. . . .Abrupt external pressures, transmitted hydraulically through the blood vessels, may exceed the rupture points of small vessels in various organs including the eye.

As the above quotation indicates, this task is another of the research activities of the Aeromedical Field Laboratory with a bearing on high-speed escape from aircraft. But the range of possible applications extends far beyond the escape problem. The physiological effects to be studied by this research task are also present in explosions, for instance atomic blasts, and are relevant to various problems of manned space travel. Recent interest in the use of a fluid medium for attenuating the acceleration and deceleration forces encountered in rocket flight makes experimentation on the effects of various pressure patterns extremely pertinent; conceivably, the attenuation of g-forces would be offset (at least in part) by a sharp build-up of pressure, caused by the g-loading and increased weight of the fluid itself. Finally, there is a need for basic research to distinguish the effects of pressure change **per se** from the effect of other forces that in practice may be applied at the same time. However, the Aeromedical Field Laboratory is primarily interested in positive not negative pressure changes--in compression not decompression--since the latter is already a subject of extensive research at the Aero Medical Laboratory of Wright Air Development Center. Some work is also being done at different locations on abrupt positive pressure change --using shock tubes and other specialized test facilities--but there is need for much more research on the subject.[48]

Although the Aeromedical Field Laboratory has been devoting intermittent ef-



Car Crash With Dummy Subject

forts to this task since 1955, no actual tests have yet been performed. As a result of manpower and fund limitations, the task has not progressed beyond the stage of planning and preparations. Certain items of test equipment have been assembled, and members of the laboratory staff are familiarizing themselves with their operation. Other items have been designed (with help from other units of the Air Force Missile Development Center's Directorate of Research and Development), including principally a chamber capable of exerting "pressure in the range of 1 to 5 atmospheres to the body surface of rabbits."[49] But the Center is still in the process of obtaining the apparatus, which probably will not be available until the latter part of 1958. It will then be used in exploring the effect of varying combinations of magnitude, onset, and duration of compression on animal test subjects. Ultimately, it may be desirable to obtain larger and more exacting equipment for testing similar pressure changes with primates and human subjects, but small animals must first lead the way.[50]

Automotive Crash Forces

The one remaining research task of Project 7850 is Task 78507, Automotive Crash Forces. This was one of the first subdivisions of Project 7850 to become active as a separate task, but it also deserves to stand slightly apart, as a concluding installment to the present study. Historically speaking, it has preserved a more sharply defined identity from first to last than most other tasks; at the same time, it is one of the better known, and less understood, of all the many activities of the Aeromedical Field Laboratory.

The stated objective of this task is:[51]

> To measure the actual forces incurred in automotive crashes. To establish criteria for modifications and specifications for vehicles, personnel restraints and. . . regulations for automotive safety.

The presence of such a task at an aeromedical research institution, as part of a project whose full title was formerly Biodynamics of Human Factors in Aviation and is now Biodynamics of Space Flight, has caused much raising of eyebrows in some quarters. Yet few have questioned the importance of the research objective, since automobile accidents rank second as a cause of death and first as a cause of hospitalization among Air Force personnel (and unquestionably first as a cause of death among Army personnel).[52] There was good reason to undertake such a program at Holloman's Aeromedical Field Laboratory in particular, in view of the extensive background of Colonel Stapp and his co-workers in the study of impact forces. Both aircraft and automotive crash forces, moreover, had much in common.

The automotive crash program was initiated as an outgrowth of discussions in the latter half of 1953 between Colonel Stapp and officials of the School of Aviation Medicine, Randolph Field, Texas. The original thought was to create a joint "Project Marionette" between Holloman and the School of Aviation Medicine, doing auto crash research as part of the School's official mission in the field of preventive surgery but "subcontracting. . .the experimental portion" (such as artificially-staged crashes) to the Aeromedical Field Laboratory.[53] However, since the actual work was to be done at Holloman, the Human Factors Office at Headquarters, Air Research and Development Command preferred to make the program a task of Holloman's Project 7850 rather than a separate joint project. It was therefore included in the original development plan for Project 7850, prepared in the spring of 1954. The Commission on Accidental Trauma of the Armed Forces Epidemiological Board duly proclaimed Holloman's Aeromedical Field Laboratory to be the sole Defense Department agency for automotive crash research, although the task was never funded or manned on lavish scale. It was, in fact, a relatively inexpensive research effort, especially as compared with the cost of burying a single airman and training his replacement.[54]

The most spectacular task activity has been the staging of actual crashes. The first such crash occurred on 10 March 1955, using two dummies, secured by lap belts, in a 1945 Dodge weapons carrier. This was essentially a trial run, uninstrumented, for what was billed as the first "full scale auto crash test" on 17 May 1955. The latter was conducted as part of an automotive safety conference held at Holloman for representatives of industry, government, and academic institutions.

Since that time there have been many more staged crashes, using Air Force salvage vehicles that are no longer worth repairing, with both dummy and animal subjects. Some have been crashes against a fixed barrier or another vehicle, while

in other cases a roll-over accident was reproduced. Most early attempts to stage an artificial roll-over were unsuccessful, but in due course the technical difficulties were overcome. One ingenious improvement, introduced in October 1957, was to do the rolling over onto a bed of worn-out rubber tires; by this means the test vehicle could be used in an experiment at twenty to twenty-five miles an hour and emerge in good enough shape to be rolled over again in later tests. Still another category of crash experiment was one in which the vehicle was suddenly stopped by means of a metal cable attached to its frame, thus allowing the study of impact forces to which interior occupants would be subjected in a crash without seriously harming the structure of the vehicle. The other end of the cable passes through a mechanical snubber that could be adjusted to produce the desired crash configuration. This equipment was supplied to the laboratory about 1 October 1957 by General Motors Corporation, for the token price of $25. Like the bed of tires, it allowed re-use of the test vehicle; and it allowed sufficiently good control for the current task scientist, Lieutenant Daniel L. Enfield, to use himself as a test subject--something he had not yet done in other types of crashes.[55]

In all these experiments, the procedure has been to measure g-forces, observe the effects either on test vehicles or on their occupants, and test the effectiveness of various safety devices. However, the work of Task 78507 has involved considerably more than staging crashes with actual vehicles. For instance, tests were conducted in August 1955 and again in June 1956 on certain energy-absorbing steering wheels developed by the Ford Motor Company. For this purpose, anesthetized hogs were placed in the Aeromedical Field Laboratory's newly-devised swing seat and then released to impact at twenty miles an hour against both conventional and energy-absorbing wheels. The results clearly showed that injuries were reduced by use of the improved steering wheel. This was a type of experimentation that the Ford engineers had been unable to perform on their own, since company legal and public relations officers flatly refused to countenance the use of test animals.[56]

The swing seat was also used in the auto crash program with dummies and human subjects, the first human test subject being Lieutenant Sidney T. Lewis, Lieutenant Enfield's immediate predecessor as task scientist.[57] Swing-seat decelerations were almost unrealistically brief as compared with forces sustained in actual crashes, but at least the contraption was easy to operate. To be sure, humans were not impacted against a steering wheel or anything else. Instead, the seat was one of various devices used to compile data on tolerance to deceleration when restrained by lap or seat belt only and to test performance of different belts, including some expressly designed for automotive use and others prepared for commercial or military aircraft.

This experimentation somewhat resembled earlier German tests of lap-belt deceleration with a swing device, but participants at Holloman endured higher g-forces. About twenty-three g's were sustained without injury on the Holloman swing seat, although for some volunteer subjects a very definite pain threshold had been reached. Using hog subjects again, swing-seat tests were held to explore the range from serious to lethal injuries caused by deceleration sustained with lap belt only. In these tests, it was found that about forty g's were needed to produce "definite injuries to lungs, heart, abdominal organs" and "something in the order of 50 g's" for lethal effects.[58]

The auto crash task has used the Daisy Track, for more lap-belt-only tests with human subjects, and to a somewhat greater extent the short Bopper or crash-restraint demonstrator. The improved model of the Bopper received in March 1956 has been used with dummy, animal, and human subjects to study deceleration with a variety of safety restraints, at forces ranging up to and slightly above twenty-five g's. In mid-1957, for instance, the Bopper was being used to evaluate a combination of conventional lap belt plus a single diagonal strap across the chest and one shoulder. Earlier, Lieutenant Lewis rode the Bopper with lap belt only to a roughly twenty-seven-g stop, sustaining considerable discomfort but no irreversible injury.[59]

The most recent test facility to be enlisted for auto crash research is the tilting seat developed by the Aeromedical Field Laboratory's Space Biology Branch for use in subgravity studies. The seat is normally placed under water, to study subject reactions under a condition of sensory deprivation simulating subgravity, but Lieutenant Enfield used it out of water in the spring of 1958, tilting the seat completely upside down. Test subjects tried to release a seat belt in the upside-down position, and information was gathered both on the speed and efficiency of different subjects and on the amount of force required for the operation.[60]

Still other work for the automotive crash program has been performed away from Holloman on a contract basis. A contract of December 1955 was signed with the University of Minnesota for designing a hydraulic bumper to absorb and reduce crash forces and also a superstructure to protect the occupants of open-top military vehicles (such as weapons carriers) in roll-over accidents. The work was entrusted principally to Professor James J. Ryan, whose final report of 31 July 1958 announced that both contract efforts had been successful. Ryan predicts that his experimental roll-over structure--a framework of metal tubing extending above the vehicle occupants--will give protection from any but "superficial injuries," in roll-overs at speeds up to forty miles an hour. It is assumed, of course, that the occupants must also have "adequate seat-belt support." The hydraulic bumper has brought impact forces in a thirty-mile-an-hour, solid-barrier collision to within human tolerance limits, again assuming the use of safety-belt restraint; in fact it has absorbed as much as eighty-five per cent of total initial impact energy in tests with a weapons carrier.[61]

A second contract was signed in 1956 with the Institute of Transportation and Traffic Engineering of the University of California at Los Angeles, whose crash injury research program dates back to 1948. In this case, the purpose was to conduct a series of instrumented collision experiments that would supplement the data gathered in crash experiments at Holloman. Since the Institute could devote more personnel and resources to this type of work than could the Aeromedical Field Laboratory itself, results have been quite satisfactory. The contract should be completed by the end of 1958.[62]

The Holloman auto crash program has been closely coordinated with still other outside institutions, beside the two universities holding crash research contracts. For instance, the crash injury research program at Cornell University Medical College supplied statistical data from actual highway crashes to be used in planning tests at Holloman.[63] Still wider coordination was obtained by holding regular meetings at Holloman Air Force Base with industrial, civic, and academic representatives interested in automotive safety problems. The public demonstration held in May 1955, which really marked the formal inauguration of the Holloman program, was followed by similar gatherings in October 1956 and November 1957.[64] Nor did Colonel Stapp, in particular, wait for these annual meetings in order to speak out on automotive safety problems, and above all on the case for safety belts, which has been further strengthened by results of the Holloman crash program. Colonel Stapp seldom missed an opportunity to tell the public that failure to install seat belts is "negligent suicide." He has naturally installed them in his own car, and has publicly praised automobile manufacturers for their growing interest in safety devices.[65]

Thanks to the pleas of Colonel Stapp and others of like mind--including the American College of Surgeons and the Armed Forces Epidemiological Board--the armed forces have committed themselves in principle to the installation of seat belts in all military vehicles. The principle has not yet been generally applied in practice, since the services have taken ample time to work out details and weigh the pros and cons of different types of belts. Nevertheless, a start has been made toward equipping vehicles assigned to Holloman Air Force Base, and meanwhile the Aeromedical Field Laboratory has been reviewing possible seat-belt standards both for military use and for the automotive fleets of the General Services Administration.[66]

Colonel Stapp was so firmly convinced of the continuing importance of the car crash program that he sought to raise it to the status of a separate project rather than merely a task of Project 7850. In 1956, this move was approved both at Center level and at command headquarters, but ultimately it failed for lack of support at Headquarters, United States Air Force, where some persons claimed that enough information on automotive crash forces was already available.[67] No doubt the rejection of the new project also reflected enduring skepticism in some quarters as to the advisability of doing automotive research at an aeromedical laboratory.

Criticism of the Holloman car crash program briefly came to a head in the summer of 1957, following the publication of illustrated news stories concerning crashes staged by Mr. Derwyn Severy of the Institute of Transportation and Traffic Engineering, University of California at Los Angeles. Severy was directly in charge of the crash research contract entrusted to the Institute by the Aeromedical Field Laboratory, so that the Air Force was duly mentioned in connection with this publicity; and when the stories showed late-model sedans being crashed for research purposes there were some persons, including at least one Congressman, who concluded that the Air Force was purchas-

ing new cars just to have them wrecked. Actually, of course, Severy does research for other sponsors as well, including automobile manufacturers, and no late models were ever crashed on behalf of the Holloman program. At the same time, Severy himself was quoted as saying that a seat belt to save lives in a head-on high-speed collision had not yet been devised--a technically true statement but one that, in its context, could easily suggest that the merits of seat belts were being exaggerated by such proponents as Colonel Stapp. Certainly the opponents of the seat-belt campaign did not fail to make this point.[68]

The entire affair was summed up by Colonel Stapp as a "ridiculous series of publicity blunders and Congressional trumpeting resulting therefrom,"[69] but it was enough to hearten critics of the Holloman crash program, while the fear of "Congressional trumpeting" made officials at higher headquarters understandably hesitant to rush to the program's defense. Nevertheless, this minor tempest was followed by an important triumph. It was one more reason for Colonel Stapp's co-workers and allies in the industrial and academic fields, such as Mr. John O. Moore, head of the Cornell crash research program, to arrange a personal appearance for him before the House of Representatives Special Subcommittee on Traffic Safety. This subcommittee, headed by Congressman Kenneth A. Roberts of Alabama, was just then investigating the very subject of automotive safety devices. When Colonel Stapp gave his testimony, on 5 August 1957, he was able to clear up misconceptions that had arisen and thoroughly convinced Roberts and other Congressmen of the value of the Holloman crash research program. Congressman Roberts even went so far as to assure Colonel Stapp that he should have no worry about funds for his automotive crash research in the next year's budget.[70]

Unfortunately for the auto crash task, the Air Force itself decided that this program should be phased out by October 1958,[71] and Congress did not try to overrule the decision. Even if the task had not been formally cancelled, it would have enjoyed extremely low priority amid all the biosatellite efforts and related workload assigned to the Aeromedical Field Laboratory in the course of 1958.

Nevertheless, it is worth noting that in November 1957 the laboratory held the last, the most elaborate, and certainly the most interesting of all its yearly meetings with outside representatives on automotive crash problems. Entitled Third Annual Automotive Crash and Field Demonstration Conference, it brought over a hundred persons to Holloman for a three-day session and featured research papers and discussion, demonstration of safety devices, actual automotive crashes, and impact tests on such facilities as the Bopper and the Daisy Track. Professor Ryan of the University of Minnesota demonstrated the bumper and the roll-over structure he was working on under contract. Another highlight was the first use of one of the laboratory's recently acquired bears as a test subject, on a twenty-g Daisy Track deceleration run. This in itself was bound to attract attention, because the bears' arrival just a few days before had already received an unwelcome wave of publicity, and also because of the mere fact that an early press story concerning the conference had mistakenly announced a pig experiment instead. An official release clearing up the latter point gave rise to the classic headline (conceived, of course, by Colonel Stapp): "Pig Tale Disproved by 'Bear' Facts."[72]

This release failed to mention that the bear (having shown no outward ill effects of the ride) was later sacrificed in order to look for possible internal injury. Yet that detail, too, was soon featured on the front page of the **Alamogordo Daily News** and at least mentioned in other papers as well. Indeed, some of the publicity about the conference was just plain unfavorable. One visitor, in particular, was highly offended when another prepared release was politely but firmly taken out of his hand by a young lieutenant at the Center's Information Services Office. The release in question was quite innocuous; it contained a statement by Indiana Congressman John V. Beamer, another attendant at the conference who highly praised the entire car crash program, and it also made brief reference again to the bear experiment. But it could not be distributed publicly until cleared by higher headquarters. The visitor out of whose hand it was lifted then poured out his grievance in angry terms to the **Alamogordo Daily News,** which included it in the same feature story that openly discussed the bear's death.

The local paper--whose general treatment of the Center has been extremely cordial--threw in for good measure the complaint of a Chicago reporter that he had been "bounced off the base" soon after he arrived to cover the conference. In effect, there had been some undeniable confusion as to whether or not press coverage would be allowed, involving higher headquarters as well as different units of the

Air Force Missile Development Center. It was also true that in the end all reporters who so desired, whether from Chicago or from Alamogordo, were permitted to attend. And it is possible that even the less favorable publicity may have done some good, indirectly, by reminding people of the conference and of its basic theme--automotive safety.[73]

One reason why the bears' arrival attracted wide attention was that they reached the Air Force Missile Development Center just after the Soviet Union shot off a dog in Sputnik II. There was speculation that perhaps the United States Air Force planned to outdo the Russians by placing not a mere dog but a great big bear in orbit. Actually, of course, there was no such intention; yet it was not far-fetched to make at least some connection between bears at Holloman and travel through space. G-forces are g-forces, whether experienced on the highway in an auto crash, in emergency escape from aircraft, in landing on Mars, or in returning again to Earth. Patterns and orders of magnitude naturally vary in all these cases, but the cases do have some points in common. Thus with the same test facilities, and within the same program of deceleration and impact tests, the Air Force Missile Development Center's Aeromedical Field Laboratory has made contributions toward the solution of an extremely broad range of operational problems. This is in addition to the service it has performed in compiling basic research data on human and animal g-tolerances. The study of deceleration and impact, along with the Aeromedical Field Laboratory's research on windblast and on such branches of space biology as cosmic ray hazards and subgravity, must therefore be listed among the truly significant accomplishments of the Center.

NOTES

1. **Major Achievements in Biodynamics: Escape Physiology at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1953-1958** (Holloman AFB: AFMDC Historical Office, June 1958).

2. RDB Project Card, Biodynamics of Human Factors in Aviation, 23 April 1954; R & D Project Card (DD Form 613), Biodynamics of Space Flight, 19 March 1958.

3. Center briefing, by Lt. Col. Rufus R. Hessberg, Jr., Chief, Aeromedical Field Laboratory, 8 September 1958; interview, Col. John P. Stapp, Chief, Aero Medical Laboratory, WADC, by Dr. James S. Hanrahan, Center Historian, AFMDC, 9 September 1958.

4. "Project 91 - MX-981 - Aero Med Sled Run Data -- Holloman Track," Issue III, 1 May 1957.

5. Aeromedical Field Laboratory, **Test Report on Escape from Aircraft at High Speed and Altitude,** No. 2, 21 June 1955.

6. **Ibid.;** Project MX-981, **Weekly Test Status Report,** 26 April, 3 and 24 May, 21 June 1955; R & D Project Card, Biodynamics of Human Factors For [sic] Aviation, 8 February 1957, p. 7.

7. Lt. Sidney T. Lewis and Col. John P. Stapp, **A Crash-Restraint Demonstrator** (HADC Technical Note 57-9, June 1957); "Abstracts of Scientific Papers. . .," **Journal of Aviation Medicine,** Vol. 27, p. 173 (April 1956); **Aviation Week,** 13 May 1957.

8. RDB Project Card, Biodynamics of Human Factors in Aviation, 23 April 1954; ltr., Mr. Alan C. Morgan, Director, Customer Relations, Northrop Aircraft, Incorporated, Hawthorne, Calif., to Hq., HADC, subj.: "Aircraft Crash Force Program," 20 July 1954; R & D Project Card, Biodynamics of Space Flight, 19 March 1958, p. 1.

9. **Major Achievements in Biodynamics: Escape Physiology, passim.**

10. "Project 91, Performance Data," 5 July 1957, chart in library of Aeromedical Field Laboratory; ltr., Lt. Col. John P. Stapp, Chief, Aeromedical Field Laboratory, to Maj. Rufus R. Hessberg, Jr., Chief, Biophysics Branch, Aero Medical Laboratory, WADC, subj.: [Windblast Tests], 2 January 1957; interviews, Capt. John D. Mosely, Chief, Biodynamics Branch, Aeromedical Field Laboratory, by Dr. David Bushnell, AFMDC Historian, 13 November 1957 and 7 February 1958; interview, Col. John P. Stapp, Chief, Aeromedical Field Laboratory, by Dr. Bushnell, 11 February 1958; "Chimpanzees Pass Space Speed Test," **New York Times,** 31 January 1958.

11. **New York Times,** 31 January 1958.

12. Capt. Stuart Bondurant, **et al., Human Tolerance to Some of the Accelerations Anticipated in Space Flight** (WADC Technical Report 58-156, April 1958) discusses relevant centrifuge experiments. The most conclusive animal experiment is, of course, the achievement of Russian scientists in accelerating a dog into orbit with Sputnik II.

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40. Aeromedical Field Laboratory, "Historical Data . . . 1 January through 31 March 1958," p. 12; R & D Project Card, Biodynamics of Space Flight, 19 March 1958, p. 2.

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43. Project 7850, **Weekly Test Status Report,** 7 June 1955; interview, Col. Stapp by Dr. Bushnell, 11 February 1958.

44. Aeromedical Field Laboratory, "Historical Data. . . 1 July through 30 September 1957," p. 3.

45. **Ibid.**; Aeromedical Field Laboratory, "Historical Data. . . 1 October through 31 December 1957," pp. 4, 5; interview, Lt. John A. Recht, Asst. Chief, Laboratory Services Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 27 November 1957.

46. R & D Project Card, Biodynamics of Space Flight, 19 March 1958, p. 4.

47. Hubert C. Feder, **Specifications for Equipment for Testing Experimental Animals Under Rapidly Changing Pressure Conditions** (AFMDC Technical Memorandum, October 1957), p. i. The quotation is from an introduction by Capt. Patterson.

48. Interview, Capt. Donald F. Patterson, Task Scientist, Tolerance to Total Pressure Change, by Dr. Bushnell, December 1957; **Aviation Week**, 3 February 1958; Aeromedical Field Laboratory, "Historical Data. . . 1 January through 31 March 1958," p. 13.

49. Aeromedical Field Laboratory, "Historical Data. . . 1 April-30 June 1957," p. 5.

50. Feder, **Specifications for Equipment**, pp. i, ii; interview, Capt. Patterson by Dr. Bushnell, December 1957.

51. Aeromedical Field Laboratory, "Semi-Annual Progress Report. . . Project 7850," January-June 1955.

52. U. S. House of Representatives, **Report of the Special Subcommittee on Traffic Safety** (Government Printing Office, Washington, D. C., 1957), p. 2; **New York Herald Tribune**, 26 July 1956.

53. Ltr., Col. Stapp to Mr. Hugh de Haven, Director, Crash Injury Research, Cornell University Medical College, subj.: [Project Marionette], 7 December 1953.

54. R & D Project Card, Biodynamics of Human Factors for Aviation, 8 February 1957, pp. 8, 9; Aeromedical Field Laboratory, **Automotive Crash Test Program**, 17 May 1955. A small amount of similar work is being done at the Army Tank Laboratory, Fort Knox, Kentucky (Committee on Interstate and Foreign Commerce, House of Representatives, Eighty-Fifth Congress, **Hearings Before a Subcommittee. . .on Crashworthiness of Automobile Seat Belts**, Washington, 1957, p. 45), but otherwise the program of Task 78507 was unique within the armed services.

55. Project 7850, **Weekly Test Status Report**, 1 and 15 March 1955, 17 May 1955; **Test Report on Biodynamics of Human Factors in Aviation**, for tests of 2 July and 21 November 1956 (Task 78507); interviews, Lt. Daniel L. Enfield, Task Scientist, Automotive Crash Forces, by Dr. Bushnell, 18 November and 2 December 1957.

56. **Test Report on Biodynamics of Human Factors in Aviation**, for tests of 3, 4, 16, and 17 August 1955 and 8, 13, and 14 June 1956 (Task 78507); Committee on Interstate and Foreign Commerce, **Hearings on Crashworthiness of Automobile Seat Belts** (Washington, D. C., 1957), p. 25.

57. The very first task scientist was Major Joseph V. Michalski, who left Holloman in mid-1955, before the automotive crash program could gather much momentum. Lieutenant Lewis took charge of the program next, and remained as task scientist for approximately two years.

58. **Test Report on Biodynamics of Human Factors in Aviation**, for tests of 24, 29, and 30 August 1956 and 6, 13, 14 and 28 September 1956 (Task 78507); Lewis and Stapp, **Experiments Conducted on a Swing Device**, pp. 5-9; Committee on Interstate and Foreign Commerce, **Hearings on Crashworthiness of Automobile Seat Belts**, p. 39.

59. Lewis and Stapp, **Crash-Restraint Demonstrator**, pp. 1-2, 7-8; Aeromedical Field Laboratory, "Historical Data. . .1 July through 30 September 1957," p. 6; interview, Lt. Enfield by Dr. Bushnell, 18 November 1957; Committee on Interstate and Foreign Commerce, **Hearings on Crashworthiness of Automobile Seat Belts**, p. 38; Lt. Sidney T. Lewis and Col. John P. Stapp, "Human Tolerance to Aircraft Seat Belt Restraint," **Journal of Aviation Medicine**, Vol. 29, p. 190 (March 1958).

60. Interview, Lt. Enfield by Dr. Bushnell, 28 May 1958. On the primary uses of this contraption, see **History of Research in Subgravity and Zero-G**, p. 22.

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62. Aeromedical Field Laboratory, "Operational Report. . .1 July 1956 through 28 November 1956;" J. H. Mathewson and D. M. Severy, "Automotive Impact Research," in National Safety Council, **Transactions**, Vol. 28, p. 94 (1954); interview, Lt. Enfield by Dr. Bushnell, 13 October 1958.

63. Aeromedical Field Laboratory, **Automotive Crash Test Program**, 17 May 1957.

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65. **Alamogordo Daily News**, 1 May and 7 September 1957; address by Col. Stapp to National Safety Forum, fall 1955.

66. Memo, Dr. Frank B. Berry, Asst. Secretary of Defense, Health and Medical, to Secretaries of Army, Navy, and Air Force, subj.: "Seat Safety Belts," 22 June 1955; Lewis and Stapp, **Crash-Restraint Demonstrator**, pp. 5-6; ltr., Lt. Col. Raymond E. Dockery to Lt. Sidney T. Lewis, subj.:

[Safety Belts for Military Vehicles], 9 August 1956; Aeromedical Field Laboratory, "Historical Data. . .1 April through 30 June 1957," p. 8; **Holloman Rocketeer,** 10 January 1958.

67. Aeromedical Field Laboratory, "Operational Report. . .1 July thru 28 November 1956;" ltr., Maj. George O. Anderson, Chief, Engineering and Research Division, Office of Assistant for Ground Safety, Hq., USAF, to Col. Stapp, subj.: [Car Crash Program], 18 December 1956; ltr., Col. Stapp to Maj. Anderson, same subject, 13 August 1957.

68. Associated Press dispatch, Los Angeles, 27 June 1957; "Big Crash For Safety's Sake," **Life,** 15 July 1957; ltr., Mr. John O. Moore, Director, Crash Injury Research, Cornell University Medical College, to Col. Stapp, subj.: [Crash Program Publicity], 11 July 1957.

69. Ltr., Col. Stapp to Mr. Moore, subj.: [Appearance Before Roberts Subcommittee], 8 August 1957.

70. **Ibid.;** ltr., Col. Stapp to Col. Harry G. Mosely, Chief, Aero Medical Safety Division, Directorate of Flight Safety Research, Norton AFB, Calif., 8 August 1957; **New York Times,** 6 August 1957.

71. Interview, Capt. Mosely by Dr. Bushnell, 9 April 1958; memo, Lt. Col. C. C. Cain, Chief, Aero-Medical Division, Directorate of Human Factors, ARDC, to Brig. Gen. Don D. Flickinger, Director of Human Factors, subj.: "Bear Used in Experiment," 15 November 1957.

72. **Alamogordo Daily News,** 12, 13, and 14 November 1957; **Holloman Rocketeer,** 15 November 1957.

73. **Alamogordo Daily News,** 14 November 1957; **El Paso Times,** 15 November 1957; **Holloman Rocketeer,** 15 November 1957; interview, Lt. Joseph Martin, Information Services Office, AF-MDC, by Dr. Bushnell, 26 November 1957.

VI

Administrative History

of the

AEROMEDICAL FIELD LABORATORY

at the

AIR FORCE MISSILE DEVELOPMENT CENTER

1951 - 1958

ADMINISTRATIVE HISTORY

AEROMEDICAL FIELD LABORATORY

1951 - 1958

One of the principal organizations now participating in the United States Air Force's "Man in Space" program is the Aeromedical Field Laboratory of the Air Force Missile Development Center, located at Holloman Air Force Base, New Mexico. It is a small organization in terms of people and facilities, but it is one of the best known units of the entire Center, and one that has made important contributions to knowledge in the two broad fields of space biology and biodynamics. These contributions include rocket-track experiments on windblast and deceleration, extended high-altitude balloon flights with human and animal subjects, and much else besides.

The record of achievement in these fields at Holloman Air Force Base goes back to the immediate post-war years, even before the Aeromedical Field Laboratory was established. Space biology as a clearly defined field of research really began in southern New Mexico with the series of rocket flights starting in 1946 that carried fruit flies, fungus spores, and small mammals to the extreme upper atmosphere. These experiments were sponsored by different agencies, principally the Aero Medical Laboratory at Wright Field in Ohio; and the earliest launchings were all made from the Army's White Sands Proving Ground, located across the Tularosa Basin from Holloman. But Holloman played a support role in all these experiments, and in 1950 became a launch site for research balloon flights designed to study the biological effects of cosmic radiation. During 1951 and 1952, three major biological rocket flights were launched directly from Holloman. On all three flights the Aerobee research rocket was used, chiefly to explore the effects of weightlessness on mice and monkeys.[1]

Both balloon flights and Aerobee firings were activities of the Aero Medical Laboratory at Wright Field, which by then formed part of the Wright Air Development Center. The Aeromedical Field Laboratory was created in 1951 precisely as a support facility for these Wright Field projects, and as a dependency (or "field" station) of the much larger aeromedical laboratory in Ohio. However, in January 1953 the Aeromedical Field Laboratory became instead a regularly-assigned Holloman unit. Holloman's official mission was rewritten at the same time to include, specifically, research in biomedical sciences.[2] There followed a rapid expansion of aeromedical and related research at Holloman, in the course of which early efforts in space biology were continued and intensified and new tasks were added in the field of biodynamics.

These changes coincided roughly with a general reorganization of Holloman activities. Just as the Aeromedical Field Laboratory had formerly been subordinate to the laboratory at Wright Field, from July 1951 to August 1952 the New Mexico test installation as a whole had been a dependency of the Air Force Missile Test Center, Patrick Air Force Base, Florida. However, the base was removed from the Missile Test Center's jurisdiction 1 September 1952, and on 10 October of the same year, Holloman Air Development Center was created as one of the full-fledged Centers of Air Research and Development Command.[3] (On 1 September 1957, the name changed again to Air Force Missile Development Center.)

This elevation to Center status was originally made in recognition of the steady growth of Holloman test and development activities, and it gave assurance that growth would continue at a steady pace over the following years. It was only natural that aeromedical research should share in the general process of expansion, and that the now-independent Center should assume direct responsibility for operation of the Aeromedical Field Laboratory.

The Laboratory Mission and the Project Workload 1953-1958

To be sure, there was no absolute separation even now between the Aeromedical Field Laboratory and its parent organization. For a time, aeromedical officers at Wright Field continued to exercise a certain amount of supervision, formally or informally, over related work at Holloman,[4] and at all times, because of many common research interests, collaboration between the two laboratories has been necessary. There are numerous cases in which either one of the two has been specifically assigned a participating role in the other's projects. Nevertheless, for most practical

purposes, the Aeromedical Field Laboratory became an independent research organization in January 1953. Indeed, some officers at Wright Field were frankly indifferent toward the cosmic radiation program, with its primary application to ultimate space flight, that was the one active Holloman effort at that time in the field of aeromedical research. They were therefore satisfied for the Aero Medical Laboratory to divest itself of its New Mexico branch. Others may have felt that separation of the two laboratories would lead to some confusion and even duplication of effort, but were apparently reconciled to the move on the ground that it "was necessary to assist [Holloman aeromedical research] in coming of age and being accepted."[5]

The process of coming of age was greatly aided by the assignment of two new officers to the Aeromedical Field Laboratory: Major (Doctor and later Lieutenant Colonel) David G. Simons and Lieutenant Colonel (Doctor and later Colonel) John Paul Stapp. Both were intent on building up the Holloman mission in biomedical sciences, and both were destined to make a lasting impression not only on the Aeromedical Field Laboratory but on the Center as a whole. The first to be assigned to Holloman was Major Simons, who had visited Holloman before, while still a captain at Wright Field, in connection with a series of V-2 animal experiments launched from White Sands Proving Ground. After participating in two out of five aeromedical V-2 firings, Simons was transferred to the School of Aviation Medicine; he then performed a tour of duty in the Far East, returned to the United States in 1952, and after a brief tour at Wright Field was reassigned to Holloman. From January 1953 until the arrival of Colonel Stapp, he was chief of the Holloman aeromedical organization, which had formerly been headed by Lieutenant James D. Telfer. He also took over the immediate direction of the cosmic radiation balloon flights, and he gave the Aeromedical Field Laboratory the new title--at least briefly--of Space Biology Field Laboratory. This more accurately reflected both his own long-range research interests and the objectives of the continuing cosmic ray program.[6]

In April 1953, Colonel Stapp was assigned to Holloman and became the new head of the laboratory. Colonel Stapp had already won national recognition in the field of aeromedical research, chiefly for deceleration experiments that he conducted in 1947-1951 at Edwards Air Force Base, California. He then served as Chief of the Special Projects Section, Biophysics Branch, of the Aero Medical Laboratory until his assignment to Holloman. Colonel Stapp was particularly happy to accept the assignment since he wished to continue his experiments in deceleration and related fields and felt that the Holloman high-speed test track was the best available facility for his purposes.

In this manner, the Aeromedical Field Laboratory at Holloman acquired another research project, entitled Biophysics of Abrupt Deceleration (RDO 695-65), which was an effort of several years' standing originally sponsored by the Aero Medical Laboratory at Wright Field. Certain aspects of the research effort were now transferred to Holloman, although the precise relationship between Colonel Stapp's work and the laboratory at Wright Field remained for some time a source of confusion. The directive for tests at Holloman on Biophysics of Abrupt Deceleration indicated that work was to be "prosecuted as a part of RDO R695-61, 'Biophysics of Escape from Aircraft' [Project 7218]," which was a Wright Field project; but in practice Colonel Stapp was largely on his own from the moment he reached Holloman. Colonel Stapp saw fit to restore the original name Aeromedical Field Laboratory, which was broad enough to cover both his own proposed research and the work of Doctor Simons, at least until such time as Holloman space biology research literally penetrated outer space.[7]

Before long, Biophysics of Abrupt Deceleration was transformed and broadened into Project 7850, Biodynamics of Human Factors in Aviation, which was a Holloman project from the beginning. This move was sought by Colonel Stapp as a means of clearly establishing the independence of his own research. It also made specific provision for research on certain topics not covered by his original test directive. The new project was subdivided into: Tolerance to Impact Forces (Task 78503); Tolerance to Total Pressure Change (Task 78504); Tolerance to Abrupt Windblast (Task 78505); Tolerance to Aircraft Crash Forces (Task 78506); and Automotive Crash Forces (Task 78507).[8]

This general organization remained in effect until early in 1958, when Project 7850 was rewritten to bring it in line with the new emphasis on space exploration. The title now became Biodynamics of Space Flight, although aircraft still received mention in the statement of project objectives: specifically, "dynamic stress characteristics of the human body" are to be

studied as affecting the "criteria for design and specifications of aircraft and space vehicles where acceleration, pulsations, impacts, and pressure differentials are imposed under normal and emergency conditions. . . ." For that matter, the automotive crash program remained in the project as Task 78507, and both Tolerance to Impact Forces (Task 78503) and Tolerance to Total Pressure Change (Task 78504) kept their former names and virtually the same statements of aim and method. But Task 78505 now became Tolerance to Ram Pressure and Thermal Effects, and Task 78506 was changed to Patterns of Deceleration in Space Flight.[9]

Two more changes in the project organization of biodynamics research were proposed at Center level but failed to materialize. In 1956, the proposal was put forward to make the automotive crash program into a separate project of its own. Headquarters, Air Research and Development Command favored the move but it subsequently failed for lack of support at Headquarters, United States Air Force.[10] In March 1958, at about the same time that Project 7850 was revised to become Biodynamics of Space Flight, the Aeromedical Field Laboratory submitted the necessary documentation for still another project, to be known as Project 7858, Experimental Pathology of Aircraft Accident Forces. The documentation had scarcely been finished when the name of the proposed project was altered to Space and Air Experimental Pathology, "for clarity of research area involved." It was to investigate many of the same forces that were a subject of study in Project 7850, but whereas Project 7850 sought mainly to establish the limits of voluntary human tolerance, Project 7858 was to be concerned with the "grey zone" between "uninjured survival and lethality." However, the projects were still too much alike to suit higher headquarters. Project 7858 was therefore rejected at command level, mainly on the ground that it was "merely an extension of Project 7850," with certain aspects also representing duplication of work assigned to Wright Air Development Center.[11]

The project framework of research in space biology has also undergone a series of changes. The balloon flights from 1950 through 1952 (and for that matter the aeromedical Aerobee firings too) had been conducted as part of the project entitled Physiology of Rocket Flight (RDO 695-72, MX-1450R). After Major Simons arrived, a new project was established entitled Biophysics of Cosmic Radiation, which was adapted more specifically to the balloon-borne cosmic ray research in progress at Holloman.[12] Finally, in 1954 Holloman space biology research was broadened into Project 7851, Human Factors of Space Flight. In this case the development plan was dated 6 May, and command approval, with minor alterations, was granted on 24 September. The original subdivisions were Radiation Hazards of Primary Cosmic Particles (Task 78500), Subgravity Studies (Task 78501), and Descent and Recovery (Re-entry) which became Task 78502. The latter task, never very active, was eliminated early in 1958, but in 1955 still another task had been added: Environmental Control in Sealed Cabins (Task 78516). This was the task primarily responsible for the Man-High program of high-altitude manned balloon flights.[13]

A closely related effort is the new Project 7857, which was established at Holloman in the course of 1957. The title originally proposed was Research in Space Bio-Sciences, but the word "space" was still frowned upon at the time in high Defense Department circles, suggesting Buck-Rogerish fantasies and waste of the taxpayers' money. Hence the project was approved at higher echelons with a slight change in name though not in substance, becoming officially Research in Extreme Altitude Bio-Sciences. However, by the early part of 1958, and for obvious reasons, everyone was satisfied to restore the name first proposed by the Aeromedical Field Laboratory.[14]

Project 7857 was only secondarily concerned with "in-house" research efforts. Chiefly, it provided for the Aeromedical Field Laboratory to direct research on a variety of topics--radiation effects, psychophysiological aspects of weightlessness and sealed cabin environment, and so forth--through contracts with outside investigators. Such contracts had previously been awarded under Projects 7850 and 7851, but the new project envisages a definite increase in contract efforts. It supplements the other projects, and in particular Project 7851; Colonel Simons is currently project officer in both cases, and the task subdivisions of one are mostly related to tasks included in the other. Project 7857 thus broadens the research role of the Aeromedical Field Laboratory even though it does not greatly affect the scope of activities carried on locally. Air Research and Development Command refused to make funds available until full coordination was effected with related projects at other Air Force installations, and no contract had actually been signed under the terms of

Project 7857 by the end of 1957. But several were being negotiated even then, and shortly thereafter the program of contract research began in earnest.[15]

Despite the addition of Project 7857, most of the work of the Aeromedical Field Laboratory still centers around the two earlier Projects 7850 and 7851. Indeed the establishment of these two projects--both created by and for the Aeromedical Field Laboratory--might well be described as the definitive step in the "coming of age" of the Holloman unit. Moreover, there gradually developed an official concept of division of effort between the laboratories at Holloman and Wright Field. The latter was to take charge of short- and medium-term research, including all development of equipment. The Holloman effort was to be devoted to more long-term research, keeping five or more years ahead of actual weapons systems development. Naturally, this official reasoning was not, and was scarcely expected to be, applied literally in all cases. One conspicuous exception was the existence of automotive crash research as a Holloman task. This had no obvious relation to long-range weapons systems development, and investigated (among other things) seat belts and safety devices for immediate use. Nevertheless, the distinction in time phasing did provide a useful frame of reference for planning purposes; and, in practice at any rate, duplication of effort between the two laboratories did not become too serious. General Don D. Flickinger, after becoming Director of Human Factors for Air Research and Development Command in mid-1957, stated that, while some overlapping might exist, it was not a real problem. He also expressed his satisfaction with the continuing independence of the two laboratories.[16]

Toward the end of 1957, still another concept emerged at command level, to the effect that Wright Air Development Center's Aero Medical Laboratory should become the primary agency for directing biomedical research, with the Air Force Missile Development Center's Aeromedical Field Laboratory serving essentially as a "test center."[17] This policy, as adopted by General Flickinger and others in authority, appeared to represent a distinct cutback for the Holloman research mission. However, it was far from clear at the time just what the practical effect would be. For one thing, it became known almost simultaneously that Colonel Stapp was slated to move to Wright Field and become head of the Aero Medical Laboratory there, which he did in April 1958. Any cognizance over Holloman projects that may be vested in Wright Field would still be exercised in large measure by Colonel Stapp, thus guaranteeing a certain continuity. Then, too, the line between research and testing is even harder to draw in aeromedical projects than in missile development, and is subject to varying interpretations to say the least. Finally, it is worth noting that the change in the Aeromedical Field Laboratory's mission was proposed at the same time as important new funds were being made available both for new facilities and for research operations.[18]

A project that offers obvious complications, if the Aeromedical Field Laboratory is to be conceived primarily as a test center, is the new Project 7857, Research in Space Bio-Sciences. Already the Directorate of Life Sciences (formerly Human Factors) at command headquarters has moved to eliminate some of the tasks of this project. Among those called in question are several that had not been fully activated, and which possibly do represent unnecessary duplication of work being done elsewhere in the command. On the other hand, Task 78530, Psychophysiology of Weightlessness, has also been threatened, despite the fact that it is an integral part of a long-standing Holloman subgravity program that has absolutely no counterpart anywhere in Air Research and Development Command.[19] Accordingly, effort that could better be devoted to doing scientific research must be diverted to arguing over research responsibilities--a state of affairs that has been regrettably common in the brief history of the command, and not only in the area of life sciences.

Even while the Aeromedical Field Laboratory was entering a period of some uncertainty with regard to its official mission, members of the laboratory's staff were being called upon to take a prominent role in Air Force-wide and interservice efforts for placing man in space. During his last months as head of the Aeromedical Field Laboratory, Colonel Stapp spent much of his time at command headquarters helping General Flickinger to draft the Air Force's own "Man in Space" program. Colonel Simons, who again became chief of the laboratory on Colonel Stapp's departure, has served as chairman of the interservice Biosatellite Coordination Committee. Other Holloman aeromedical scientists have been assigned to the same Committee, as well as participating in various inter-agency projects for the use of ballistic-type missiles in biological research. Such inter-agency and interservice pro-

jects have helped create a critical condition of overwork among the Holloman staff members. But the Holloman role in such endeavors is one reason why the Aeromedical Field Laboratory's research and development program in fiscal year 1958 was funded at more than $2,000,000, as compared with $260,000 in fiscal 1956.[20]

Administrative Organization and Resources

Needless to say, the reshuffling and expansion of project workloads that has been going on since the start of 1953 has been accompanied by a series of administrative reorganizations within the Aeromedical Field Laboratory. The most important innovation was to split the original organization of the laboratory into two main operating divisions, which was an obvious requirement once Colonel Stapp introduced a program in biodynamics alongside the earlier research in space biology. These two divisions are known today as the Biodynamics Branch and the Space Biology Branch, the one in charge of Project 7850 and the other conducting Projects 7851 and 7857; but the exact names have varied at different times in the past.

The present Biodynamics Branch, when first organized in 1953, bore the curious title of Liaison Projects Section. At first this Section was headed directly by Colonel Stapp, with the help chiefly of Master Sergeant James F. Ferguson, who had collaborated with Colonel Stapp at Edwards and who was brought to Holloman by Stapp as soon as possible after his own assignment to the New Mexican installation. The Section was then primarily responsible for Colonel Stapp's work on Biophysics of Abrupt Deceleration, and its title reflected, among other things, the interrelation between that work and related crash and escape studies of the Aero Medical Laboratory at Wright Air Development Center. It was also to assist Wright Field scientists in certain other tests that they intended to conduct at Holloman for their own research tasks; and it contained, at least on paper, a Bio-Acoustics Unit which was supposed to cooperate with Wright Air Development Center in a ten-year program of research on aircraft noise. In practice, however, neither the noise program nor the unit created for that purpose ever became active. Hence the Bio-Acoustics Unit was omitted from the organization charts by September 1955, if not earlier. At the same time, the Liaison Projects Section as a whole received its current name of Biodynamics Branch, with its functions redefined to fit Project 7850 more closely. For about a year during 1954-1955, it also received a distinct branch chief, Major Joseph V. Michalski. The position was then filled once more by Colonel Stapp himself, in addition to his duties as head of the entire laboratory, until the assignment of the present chief, Captain (Doctor) John D. Mosely, in the latter part of 1956.

The present Space Biology Branch has had a less varied history. The only change in its title has been to delete the original term "Section" and substitute "Branch." Its functions--starting with cosmic radiation balloon flights and later taking in other research activities of Projects 7851 and 7857--have been easily recognizable from the name of the unit, and its chief since 1953 has been Colonel Simons. There have, of course, been various changes in name and function among the subunits of both major branches, in addition to the rise and fall of the Bio-Acoustics Unit mentioned above; but these changes have been of relatively minor importance. Finally, the Aeromedical Field Laboratory has always had one or more units in charge of laboratory services and the like, which are currently centralized in a Laboratory Services Branch. But the existence of the last-named branch, and of its various predecessors, has not affected the basic two-fold division of the Aeromedical Field Laboratory for project work.

In its relation to other assigned activities at Holloman, the Aeromedical Field Laboratory in 1953 was placed directly under the Center's 6580th Test Group, and was thus on an equal standing with the 6580th Missile Test Squadron and the 6580th Special Test Squadron (which in turn included the Holloman Balloon Unit). Following the establishment of a Directorate of Laboratories in 1955, the aeromedical organization became one of its major subdivisions, and in 1956 the Aeromedical Field Laboratory was made part of a newly created Directorate of Research and Development. Yet, in practice, Holloman officials have generally recognized the unique role of the Aeromedical Field Laboratory, and have given a free hand as far as possible to Colonel Stapp, Colonel Simons, and their associates.[21]

Early in 1957, Major General Leighton I. Davis, Commander of the Air Force Missile Development Center, proposed raising the Laboratory to the status of Directorate of Space Biomedical Sciences. General

Davis submitted to higher headquarters a plan that could be initiated "within the present manning resources of the center" but would prepare the way for major expansion as soon as funds and manpower became available. General Davis proposed separate Divisions for Administration; Plans; Services; Biodynamics; and Human Factors Development. The Human Factors Development Division was to be essentially an outgrowth of the current Space Biology Branch, with special emphasis on problems of true space flight including those involved in preparation of a manned satellite. It was also proposed that the new directorate might offer resident training to candidates seeking certification by the Aviation Medicine Board.[22]

The proposal to create a Directorate of Space Biomedical Sciences at Holloman was in line with recommendations made by a number of high-level Air Force planning committees, including the Long-Range Planning Committee for Guided Missiles and Space Vehicles of the Air Research and Development Command, which is usually referred to as the Yates Committee. At the same time, it should be noted that the exact timing of the proposal was probably influenced by the fact that John Paul Stapp had just been promoted from Lieutenant Colonel to Colonel, effective April 1957. As head of the Aeromedical Field Laboratory, he was technically subordinate to the Center's Directorate of Research and Development, which was then headed by a lieutenant colonel. However, the new directorate was ultimately rejected at command headquarters. Brigadier General Don R. Ostrander, Deputy Commander for Resources, Air Research and Development Command, explained that the proposal was unacceptable because it entailed an increase in the number of administrative spaces and because it went against the command effort to "consolidate functions."[23]

Despite the unfavorable decision in this instance, the steady expansion in the work of the Aeromedical Field Laboratory inevitably brought with it an increase in both assigned personnel and facilities. Personnel strength has not kept pace with the increase in project work, but has risen gradually from the mere handful present in January 1953 to a total in June 1958 of thirteen officers, eighteen airmen, and sixteen civilians.[24] All of the officers hold college degrees in some scientific field, and eight of the thirteen (plus one civilian scientist) have the doctor's degree. This last is a fairly remarkable proportion, indicative of a small but exceptionally qualified corps of scientists.

New buildings were added in the same period. As of January 1953, there were two in use (Buildings 1201 and 1203, one permanent and the other a converted wartime "temporary" structure), but since then two more permanent structures (Buildings 1200 and 1202) have been added to the aeromedical laboratory complex in the Holloman "North Area" along with a converted wartime barracks to serve as supply warehouse (Building 1240). A fine new warehouse is to be started in the immediate future, but the special medical science laboratory that was to have been included in fiscal year 1959 building plans has been put off for another year. This is especially unfortunate, since the buildings that exist in the present laboratory complex are cramped, one-story, and in some cases rather dingy structures. The one exception is a portion of the more spacious Building 1265, chiefly housing offices of the Center's Directorate of Ballistic Missile Test, which has been made available to staff members of the Space Biology Branch.[25]

A number of specialized test facilities, too, have been created at Holloman either expressly for the Aeromedical Field Laboratory or under the jurisdiction of some other unit but available for biomedical research. Most of these facilities can best be discussed in other monographs related to the particular fields of research for which they are used. The one "test facility" that it is more convenient to describe at this point, because of its use for both biodynamics and space biology research, is the Holloman "zoo" of test animals. This dates back to the period before 1953, but has greatly expanded from that year to the present.

Unlike the "zoo" which Colonel Stapp had formerly used for research at Edwards Air Force Base, managed under contract by a private animal trainer, the Holloman facility was always run by trained personnel of the Aeromedical Field Laboratory. The result has been better care for the animals, along with considerable savings for the government. From August 1954 to July 1956, the animals were entrusted to Lieutenant (later Captain) Clinton D. Hughes, a member of the Air Force Veterinary Corps, and Holloman officials were therefore alarmed when, about May 1956, the Defense Department suddenly moved to disband the entire Corps. General Davis, as Center commander, submit-

ted a strongly worded protest to the Surgeon General, United States Air Force, detailing the benefits received at Holloman from Air Force Veterinary Corps members not only in the care of test animals but also in food inspection and similar areas. Colonel Stapp likewise sounded his protests far and wide; and the messages from Holloman, joined with those from other Air Force installations, have so far helped to prevent disbandment of the Corps.

When Captain Hughes left the service, he was replaced by another Air Force Veterinary Corps officer, Lieutenant (later Captain) Donald F. Patterson. In due course, a second veterinary officer, Lieutenant John A. Recht, arrived to help. They were assigned as Chief and Assistant Chief respectively of the Laboratory Services Branch, until February 1958, when Captain James Ellsworth Cook (also a veterinarian) was assigned as branch chief and Lieutenant Patterson became Chief of the Veterinary Services Section of the Branch. However, not one of these officers can be described merely as an animal-keeper. All have assumed a share of regular project work, as have other Air Force veterinarians (including Doctor Mosely) who are assigned directly to the operational branches. Cook, Patterson, and Recht have conducted specific research tasks either wholly or in part, and have assisted their colleagues in scientifically evaluating the results of animal experiments.[26]

The animals themselves have included mice, hamsters, dogs, and cats--small animals of the type used even before 1953 in subgravity and cosmic radiation studies. From 1953 to the present, primarily for work in biodynamics, chimpanzees, hogs, and bears have also come to live at Holloman. Bears were the latest addition, when a group of four arrived in November 1957 amid a wave of unwelcome publicity. They had been purchased from the Catskill Game Farm, Catskill, New York, whose owner gave out details of the purchase in what was apparently an advertising gesture. The story was readily played up in the national press, since it came just a few weeks after Russian scientists launched a dog-carrying satellite. It thus inspired speculation as to whether the United States Air Force meant to outdo the Russians by launching a bear satellite. This was not, of course, the intention; the bears had been acquired to participate in research programs already underway at Holloman.[27]

A wide variety of animals is required for research at Holloman because no one animal is suited for all test purposes. As Colonel Stapp remarked to a Congressional subcommittee:[28]

> You wonder why I use hogs--hogs and chimpanzees? Well, man is somewhere between the hog and the chimpanzee. Some people are more like hogs; others are more like chimpanzees.

In over-all proportions and in some details of internal structure the chimpanzee--for example--is actually quite similar to man, but in certain aspects of spinal structure the bear seems a better fit. Bears had the added advantage of being cheaper and more plentiful than chimpanzees. Hogs, of course, are the most plentiful of all, at least among the large animals, and in addition have their points of resemblance to the human body. They are also the most edible, but allegations are only in jest that they are used by the Aeromedical Field Laboratory because they make good barbecue material. If sacrificed during or after a test, hogs are upon occasion presented to different units at Holloman, including the Aeromedical Field Laboratory itself, for use in group picnics, but this is only incidental to their primary research function.[29]

The Holloman "zoo" is really a unique facility within the Air Force. Some other Air Force agencies have collections of small laboratory animals, but the Aeromedical Field Laboratory is the only one with bears, hogs, and chimpanzees. It is also the only one with equipment, accommodations, and technical experience for keeping the larger test animals. Thus, in addition to supplying its own needs, it has often provided animal subjects for experiments performed away from Holloman by other Air Force scientists. Specifically, the Aeromedical Field Laboratory has given chimpanzee support to the Aero Medical Laboratory of Wright Air Development Center for different series of experiments related to high-speed escape from aircraft,[30] a field of research in which both laboratories have made significant contributions.

Those and other contributions are treated--as already indicated--in separate historical studies, each covering a particular area of research accomplishment at the Aeromedical Field Laboratory. The present history of changes in the Laboratory's mission and organization is, by comparison, a much less significant study. However, administrative problems and policies can both help and hinder a research agen-

cy. In the case of the Aeromedical Field Laboratory, Center-level administrative actions have in general been extremely favorable to its research program. The same cannot always be said of command-level and intra-command actions--at least not from the viewpoint of the local organization itself. Yet, despite all such problems, and despite inadequacies of both facilities and personnel, the Aeromedical Field Laboratory has managed to build up a justly admired record of achievements. It has acquired an expert staff of scientists and a broad capability in space biology and related fields that make it one of the key Air Force units, though by no means the only one, currently engaged in preparing man's conquest of space.

NOTES

1. See **The Beginnings of Research in Space Biology at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico, 1946-1952** (Historical Division, AFMDC, January 1958).

2. Maj. David G. Simons, **Stratosphere Balloon Techniques for Exposing Living Specimens to Primary Cosmic Ray Particles** (HADC Technical Report 54-16, November 1954), p. 4.

3. **History of Holloman Air Development Center, 1 January-30 June 1955,** pp. 9, 10.

4. Interview, Col. John P. Stapp, Chief, Aeromedical Field Laboratory, by Dr. David Bushnell, AFMDC Historian, 9 October 1957.

5. Interview, Maj. David G. Simons, Chief, Space Biology Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 6 September 1957; Memo, Capt. Edward G. Sperry, Aero-Medical Division, Directorate of Human Factors, Hq., ARDC to Col. Philip H. Mitchell, Director of Human Factors, subj.: "Goals for FY 58," n.d., p. 2. The phrase quoted in the text is from Captain Sperry's memo, and refers specifically to the transfer to Holloman (April 1953 and after) of a portion of the Aero Medical Laboratory's responsibility for direction of research on high-speed escape from aircraft. However, the same reasoning was applicable to the entire process of separation between the two organizations.

6. Simons, **Stratosphere Balloon Techniques,** p. 4; Information Services Office, HADC, news release on Maj. Simons, n.d.; Hq., HADC, **Roster of Officers Assigned,** 31 January 1953; interview, Maj. Simons by Dr. Bushnell, 6 September 1957.

7. Information Services Office, HADC, news release on Col. Stapp, November 1955; interview, M/Sgt. James F. Ferguson, Biodynamics Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 2 December 1957; ARDC Test Directive 5200-H1, "Biophysics of Abrupt Deceleration," 15 April 1953.

8. RDB Project Card, Biodynamics of Human Factors in Aviation, 23 April 1954; interview, Mr. Ellis Bilbo, Directorate of Research and Development, Hq., AFMDC, by Dr. Bushnell, 14 October 1957; ltr., Capt. Sperry to Dr. Bushnell, subj.: [History of Holloman Projects], 30 January 1958.

9. R & D Project Card (DD Form 613), Biodynamics of Space Flight, 19 March 1958.

10. Ltr., Maj. George O. Anderson, Chief, Engineering and Research Division, Office of Asst. for Ground Safety, Hq., USAF, to Col. Stapp, subj.: [Car Crash Program], 18 December 1956; ltr., Col. Stapp to Maj. Anderson, same subj., 13 August 1957.

11. R & D Project Card (DD Form 613), Experimental Pathology of Aircraft Accident Forces (proposed), 20 March 1958; Management Report (ARDC Form 111), Experimental Pathology of Aircraft Accident Forces, 4 April 1958; Maj. Frank Voltaggio, Jr., Asst. Chief, Plans and Programs Division, Directorate of Research, Dep. Cmdr./R & D, Hq., ARDC, "Critique of 80-4 Documentation," 13 May 1958.

12. Simons, **Stratosphere Balloon Techniques,** p. 4; RDB Form 1A, subj.: [Recommendation of Project Biophysics of Cosmic Radiation], 16 March 1953.

13. Ltr., Mr. Joseph General, Chief, Projects Branch, Program Administration Division, Dep. Cmdr./Technical Operations, Hq., ARDC, to Cmdr., HADC, subj.: "Approval of Project 7851," 24 September 1954; Management Report (ARDC Form 111), Human Factors of Space Flight, 1 October 1955 and 24 January 1956; interview, Lt. Col. David G. Simons, Chief, Aeromedical Field Laboratory, by Dr. Bushnell, 24 May 1958.

14. R & D Project Card (DD Form 613), Research in Space Bio-Sciences, original version of 13 March 1957 and subsequent editions of the same.

15. Aeromedical Field Laboratory, "Historical Data. . .1 October through 31 December 1957," p. 17, and "Historical Data. . .1 January through 31 March 1958," pp. 17, 18 and **passim.**

16. Memo, Capt. Sperry to record, subj.: "HADC, WADC Relationship," 29 August 1957; interview, Mr. Oliver T. Strand, Chief, Programming Branch, Operations Office, Aero Medical Laboratory, WADC, by Dr. Bushnell, 7 November 1957.

17. Interview, Brig. Gen. Don D. Flickinger, Director of Human Factors, Hq., ARDC, by Dr. Bushnell, 2 January 1958.

18. AFMDC staff meeting, 17 October 1957; ltr., Maj. Gen. Leighton I. Davis, Cmdr., AFMDC, to Brig. Gen. Don D. Flickinger, Director of Human Factors, ARDC, subj.: [Manpower for Aeromedical Field Laboratory], 13 June 1958 (with annexes).

19. Interview, Col. Simons by Dr. Bushnell, 24 May 1958.

20. Ltr., Gen. Davis to Gen. Flickinger, subj.: [Manpower for Aeromedical Field Laboratory], 13 June 1958.

21. Comptroller, HADC, **Organization and Functions,** June 1953; Manpower and Organization Division, HADC, **Organization and Functions Chart Book,** 1 September 1955, 1 March and 1 June 1956; interview, Col. Stapp by Dr. Bushnell, 9 October 1957; interview, Sgt. Ferguson by Dr. Bushnell, 2 December 1957.

22. Ltr., Maj. Gen. Leighton I. Davis, Cmdr., HADC, to Cmdr., ARDC, subj.: "Proposed Establish-

ment of Directorate of Bio-Medical Sciences," 28 March 1957; ltr., Gen. Davis to Director, Medical Staffing and Education, Medical Education Division, Office of the Surgeon General, USAF, n.d.

23. R & D Project Card (DD Form 613), Biodynamics of Human Factors for Aviation, 8 February 1957, p. 11; 3rd ind., Brig. Gen. Don R. Ostrander, Dept. Cmdr./Resources, ARDC, 27 June 1957, to basic ltr., Gen. Davis to Cmdr., ARDC, subj.: "Proposed Establishment of Directorate . . .," 28 March 1957; interview, Capt. John C. Casey, Center Plans Office, Hq., AFMDC, by Dr. Bushnell, 16 January 1958.

24. Ltr., Gen. Davis to Gen. Flickinger, subj.: [Manpower for Aeromedical Field Laboratory], 13 June 1958.

25. Real Estate Section, Air Installations, building data cards; interview, Capt. John D. Mosely, Chief, Biodynamics Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 19 June 1958.

26. Ltr., Gen. Davis to Surgeon General, Hq., USAF, subj.: "Hardships Created by Impending Disbandment of Veterinary Corps," June 1956; interview, Lt. John A. Recht, Asst. Chief, R & D Services Branch, Aeromedical Field Laboratory, by Dr. Bushnell, 27 November 1957.

27. Interview, Lt. Recht by Dr. Bushnell, 27 November 1957; **Chicago Daily Tribune,** 5 November 1957; **El Paso Times,** 5 November 1957.

28. House of Representatives, **Hearings Before a Subcommittee of the Committee on Interstate and Foreign Commerce. . . on the Crashworthiness of Automobile Seat Belts** (Government Printing Office, Washington, 1957), p. 25.

29. Interview, Lt. Recht by Dr. Bushnell, 27 November 1957.

30. **Major Achievements in Biodynamics: Escape Physiology, at the Air Force Missile Development Center. . .1953-1958** (Historical Branch, AFMDC, June 1958), pp. 32, 34.

GLOSSARY

AF	Air Force
AFB	Air Force Base
AFMDC	Air Force Missile Development Center
AMAL-NADC	Aviation Medical Acceleration Laboratory, Naval Air Development Center
AMC	Air Materiel Command
AMFL	Aeromedical Field Laboratory
ARDC	Air Research and Development Command
Asst.	Assistant
Cmdr.	Commander
Comdr.	Commander
DCS/	Deputy Chief of Staff for
DCS/O	Deputy Chief of Staff, Operations
DD	Department of Defense
Dep.	Deputy
DF	Disposition Form
EAS	Equivalent air speed
FY	Fiscal Year
HADC	Holloman Air Development Center (redesignated Air Force Missile Development Center as of 1 September 1957)
HAFB	Holloman Air Force Base
Hq.	Headquarters
Ind.	Indorsement
Ltr.	Letter
n.d.	No date
R & D	Research and Development
RDB	Research and Development Board
Sq.	Squadron
Subj.	Subject
TWX	Teletypewriter Exchange Message
USAF	United States Air Force
WADC	Wright Air Development Center

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